CORPS OF ENGINEERS, U. S. ARMY

FLOOD-CONTROL OUTLET WORKS FOR BLAKELY MOUNTAIN DAM OUACHITA RIVER, ARKANSAS

HYDRAULIC MODEL INVESTIGATION

TECHNICAL MEMORANDUM NO. 2-347

WATERWAYS EXPERIMENT STATION

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PREFACE

Authority to conduct hydraulic model investigations of the flood-control outlet works for Blakely Mountain Dam, Ouachita River, Arkansas, was granted by the Chief of Engineers in the third indorsement, dated 7 January 1948, to letter dated 12 November 1947 from the Division Engineer, Lower Mississippi Valley Division, to the Director, Waterways Experiment Station. The investigations were accomplished during the period May 1948-January 1949 in the Hydraulics Division of the Waterways Experiment Station by Messrs. R. G. Cox and N. V. Cowan, under the general supervision of Messrs. T. E. Murphy and F. R. Brown.

Messrs. E. J. Williams, J. E. Sanders, C. L. Sumrall, Jr., and F. B. Toffaleti, engineers of the Lower Mississippi Valley Division, visited the Waterways Experiment Station at frequent intervals during the course of the studies to discuss test results and to correlate these results with design work concurrently being accomplished.

CONTENTS

SUMMARY

The hydraulic characteristics of all elements of the design for the Blakely Mountain Dam flood-control outlet works were studied in a 1:25-scale model. Special attention was given to flow conditions in the conduit for various pool elevations and openings of the control gates.

Unusual flow conditions were encountered in this investigation as a result of an 80-ft drop in the section between the intake structure and conduit proper. Under certain flow conditions, hydraulic jumps formed in rapid succession near the foot of the drop and passed through the conduit to the stilling basin. Attempts made to revise the transition for improvement of these conditions were unsuccessful. However, the intake structure control gates can be operated in such a way as to preclude these unstable flow conditions.

Model tests indicated that flow conditions could be improved by a more gradual change in entrance alignment, a longer radius of the horizontal curvature of the conduit, and the use of a 7-ft vertical-faced end sill in the stilling basin. Only the latter revision was incorporated in the final design because of economic factors.

FLOOD-CONTROL OUTLET WORKS FOR BLAKELY MOUNTAIN DAM

OUACHITA RIVER, ARKANSAS

Hydraulic Model Investigation

PART I: INTRODUCTION

Pertinent Features of Blakely Mountain Dam*

1. The Blakely Mountain Dam, constructed on the Ouachita River about 10 miles northwest of Hot Springs, Arkansas (fig. 1), provides flood control and water for generation of hydroelectric power for the state of Arkansas. It is also part of the vast flood-protection system for the control of floods in the Lower Mississippi Valley. The entire reservoir project consists of a rolled earth-fill dam, power and flood-control structures in the right abutment, and an uncontrolled channel spillway located in a natural depression about 1.5 miles southwest of the dam site. The dam is approximately 1200 ft long and rises about 230 ft above the river bed. The reservoir created will impound approximately 2,800,000 acre-ft of water at spillway crest level (elev 592**) and will cover an area of about 48,000 acres.

Fig. 1. Vicinity map

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* Information obtained from "Definite Project Report, Blakely Mountain Dam and Reservoir, Ouachita River, Arkansas."

** All elevations are referred to feet above mean sea level.

2. The spillway, located to the west of the dam, is an uncontrolled structure consisting of a 200-ft-wide channel excavated in rock. It has a maximum invert elevation of 592 at the upstream edge of a 50-ft-long concrete section and a discharge capacity of 45,000 cfs at a pool elevation of 610.2.

3. The flood-control outlet works, consisting of an intake structure, a circular conduit, and a stilling basin, are designed to discharge 20,000 cfs at maximum power pool elevation of 578. The intake structure, with invert at elevation 480, contains three passages, each controlled by an 8-ft by 15-ft caterpillar-type gate. Downstream from the gates the passages converge into a transition from the gate section to the 19-ft-diameter conduit. The conduit drops in a vertical reverse curve from the junction with the transition to elevation 400 and continues about 1123 ft on a uniform slope to an invert elevation of 399 at the junction with the stilling basin. Over-all length of the conduit is 1370 ft. A 19-degree change in the horizontal alignment, effected by means of a simple curve, occurs approximately 295 ft from the lower end of the conduit. The stilling basin has an over-all length of 250 ft and is designed to dissipate, by means of a hydraulic jump, the energy of the high velocity flow issuing from the conduit. Basin elements include a horizontal apron 110 ft long at elevation 371, two rows of 8-ft-high baffle piers, and an end sill 7 ft high. General details of the outlet works are shown on plate 1.

4. The power structures located in the right abutment adjacent to the flood-control structures consist of an intake, a 24-ft-diameter steel penstock inside of a 30-ft-diameter concrete conduit, surge tank, two

16-ft-diameter steel penstocks, powerhouse and generating equipment. Installed capacity of the two units is 75,000 kw.

Purpose of Model Studies

5. The general purpose of the model studies was to analyze the hydraulic characteristics of all elements in the design of the flood-control outlet structures and to develop means of correcting unsatisfactory conditions found to exist. Special attention was to be given flow conditions in the conduit for various gate openings and pool elevations up to elevation 592 (spillway crest elevation).

PART II: THE MODEL

6. The model (fig.2 and plate 2) was built to an undistorted scale ratio of 1:25, and reproduced 250 ft of the approach area, the intake structure, transition section, the entire conduit, stilling basin and 300 ft of the exit channel. The reservoir area was represented by a steel headbay (fig. 3) equipped with baffles to provide tranquil flow conditions. The floor of the approach area was molded in cement mortar. The intake structure, transition, and entire conduit were fabricated of transparent plastic permitting direct observation of flow conditions. The stilling basin was constructed of concrete and wood to permit ready alteration of the stilling basin elements. The exit area was molded in sand for erosion tests, and was capped with cement mortar for measurement of velocities.

7. Water used for model operation was measured by means of venturi tubes before it was introduced into the model. Reservoir elevations were measured with hook gages. Numerous piezometer openings located at critical points throughout the intake structure and conduit were connected to glass manometers for measurement of pressures. Steel rails set to grade along each side of the stilling basin and exit area provided a datum plane to which all measurements were referred. A point gage, pitot tube, and sounding rod were used to obtain water-surface elevations, velocity measurements, and soundings, respectively.

8. The accepted equations of hydraulic similitude, based upon the Froudian relationships, were used to express the mathematical relationships between the dimensions and hydraulic quantities of the model and

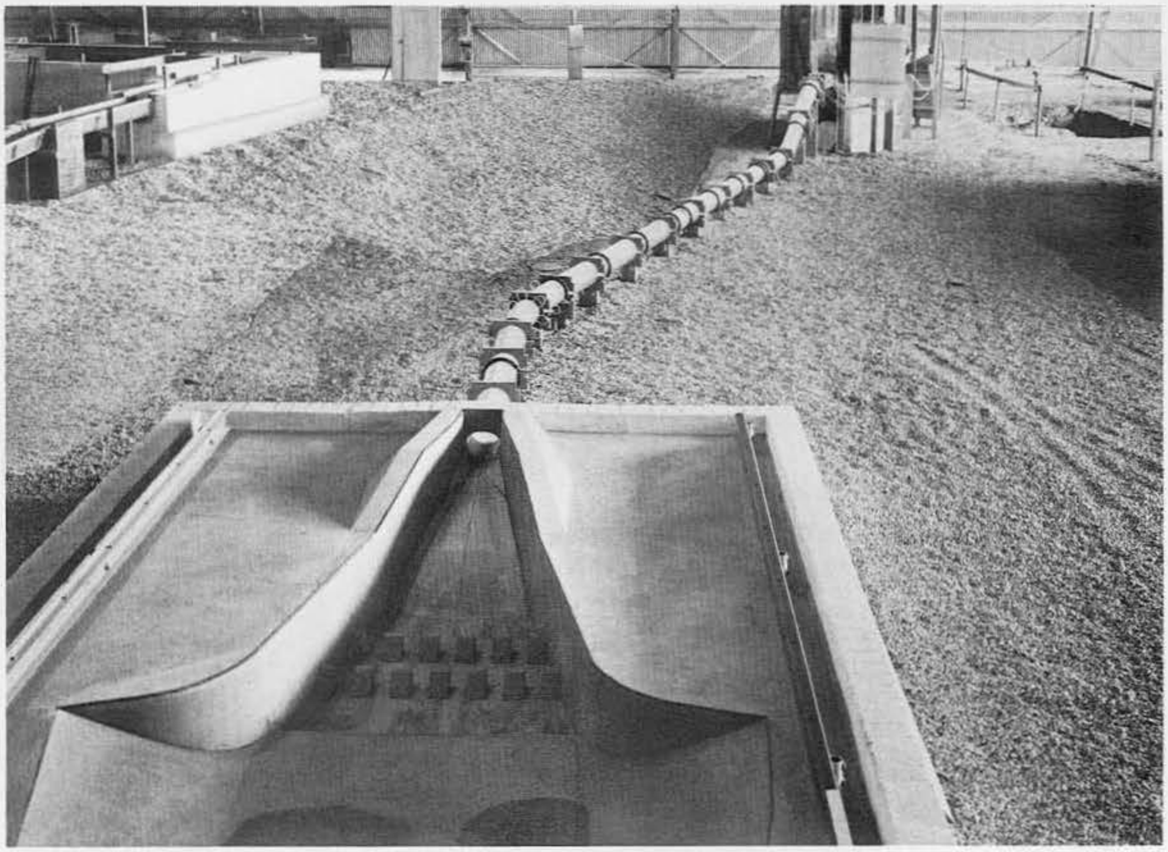


Fig. 2. General view of the model looking upstream

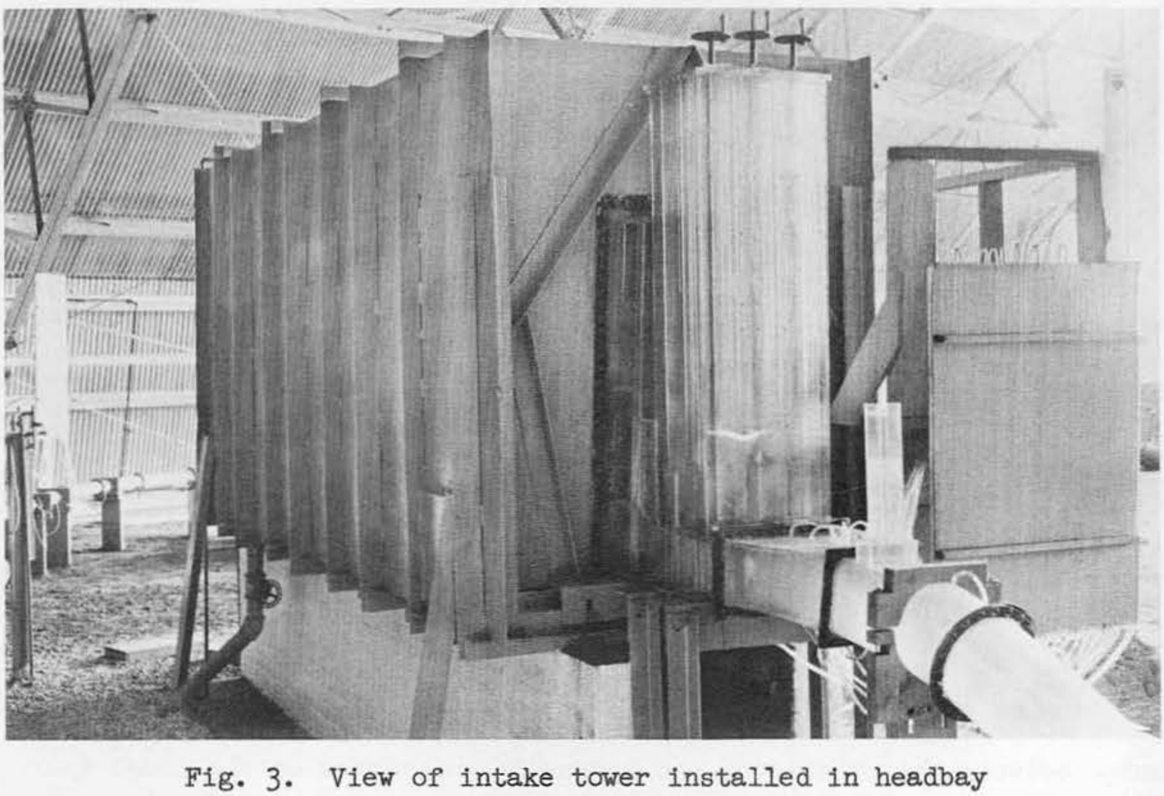


Fig. 3. View of intake tower installed in headbay

prototype. General relationships existing were as follow:

Dimension	Ratio	Scale Relationship
Length	L_r	1:25
Area	$A_r = L_r^2$	1:625
Velocity	$V_r = L_r^{1/2}$	1:5
Discharge	$Q_r = L_r^{5/2}$	1:3125
Roughness	$n_r = L_r^{1/6}$	1:1.710

PART III: TESTS AND RESULTS

Intake Structure

Description

9. The intake structure for the conduit, as previously described, consists of three streamlined passages leading to the service gates. Details of the intake structure are shown on plate 3. Each of the three passages is rectangular in shape and has a floor elevation of 480, the elevation of the approach channel. The roof of the intake is shaped to a curve following the equation $4X^2 + 9Y^2 = 900$, while the sides of the intake passages follow the curve of $X^2 + 9Y^2 = 64$. A 2-ft-wide air vent located immediately downstream from each service gate supplies air to each passage.

Tests

10. Tests of the intake structure involved the observation of flow conditions, measurement of pressures, and establishment of head-discharge relations for various gate openings and gate combinations.

11. Flow conditions. The streamlined entrance to each of the gate passages effected a quiet division of flow to the service gates for all pool elevations and various combinations of gates in operation.

12. Pressures. Pressures measured throughout the intake for various combinations of gates open full are shown in tables 1 and 2 and plate 5. Piezometer locations are shown on plate 4. Pressures were positive (above atmospheric) throughout for conditions of all gates open full and pool elevations of 592 and 578, spillway crest and maximum power pool elevation, respectively. Lowest pressures were recorded on the roof

of the intake curve. For conditions of all gates open full and a pool elevation of 542, pressures on the roof of the intake curve were negative; maximum negative pressure was -8.6 and was recorded at piezometer 11. For single gate operation negative pressures recorded at piezometer 11 were -12.6 and -11.1 for pool elevations of 592 and 578, respectively. These data indicated the roof of the curved intake to be too short for best pressure conditions; however, no revisions to the curve were investigated.

13. Head-discharge relationships. The service gates were calibrated to determine the pool-discharge relationships for full and partial gate openings, and with one, two, or three gates operating (plate 6). The model rating curve for three gates open full was in close agreement with the computed curve. The model indicated a discharge of 21,000 cfs at maximum power pool elevation (elev 578) as compared with the computed flow of 20,800 cfs. A discharge of 21,800 cfs was indicated with the pool at spillway crest elevation 592.

Transition Section

Description

14. The transition from the three gates of the intake structure to the conduit proper is approximately 150 ft long and consists of three sections (plate 7). The first section begins at the service gates and consists of three rectangular passages separated by division piers. The area at the downstream end of the passages is about 8 per cent less than at the service gates to increase pressures in the area for single gate operation. The second section begins at the convergence of the three passages and, by utilizing converging fillets with a constant radius, gradually changes

in a horizontal distance of 42 ft to a circular cross section having a diameter of 20.5 ft and an area of about 330 sq ft. The third section of the transition changes in a horizontal distance of 75 ft from the 20.5-ft-diameter section to the 19-ft-diameter conduit, having a cross-sectional area of 283.5 sq ft. The invert of the transition section follows the curve of the equation $X^2 = -450Y$ from elevation 480 at station 6+67.85 to elevation 430 at station 8+17.5. From this point the conduit curves vertically with a radius of 159.62 ft to invert elevation 400 at station 9+16.93 where it joins the 19-ft-diameter conduit of constant slope. The drop from the gate section to the conduit proper is 80 ft and occurs in a horizontal distance of 249 ft.

Tests

15. Flow conditions. Flow in the transition and conduit was unsatisfactory for certain pool elevations and gate openings (figs. 4 and 5). An unstable hydraulic jump formed in the transition section at

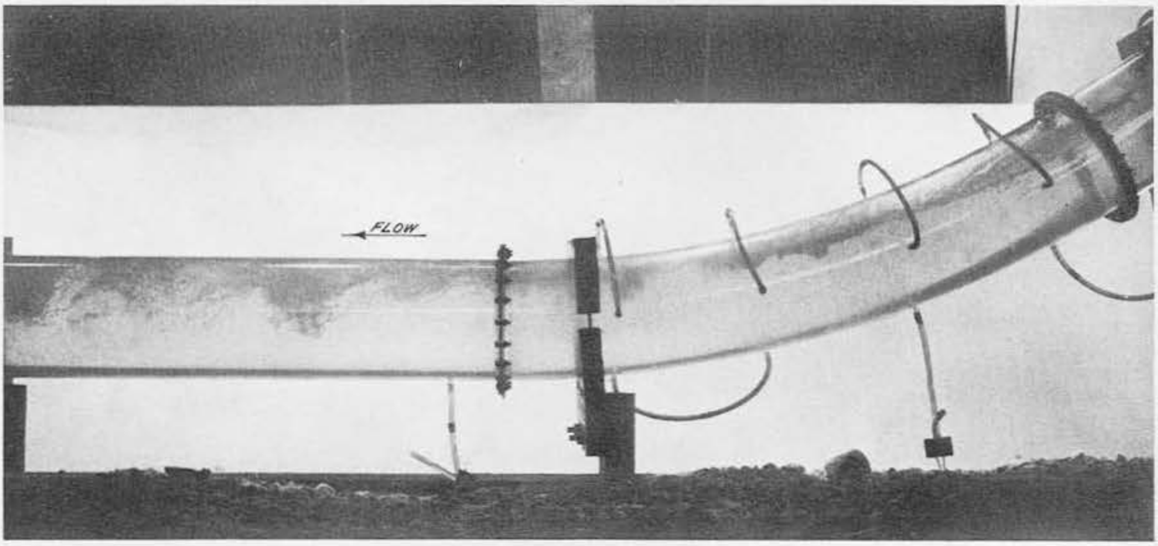
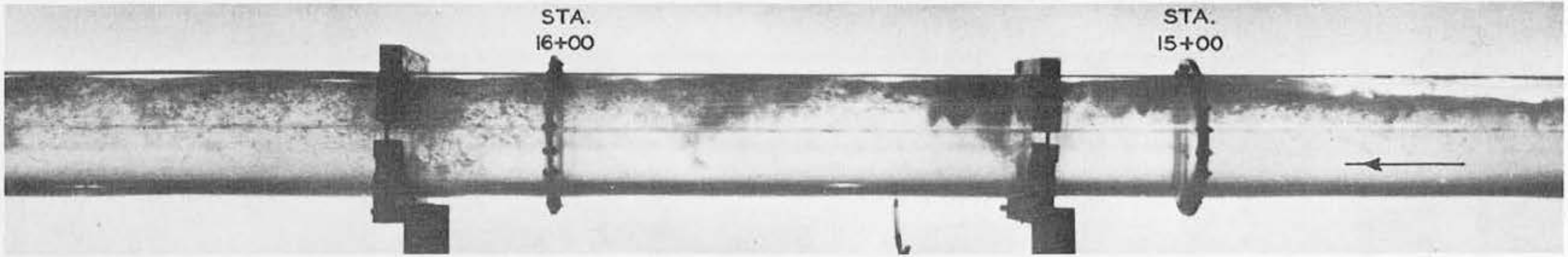
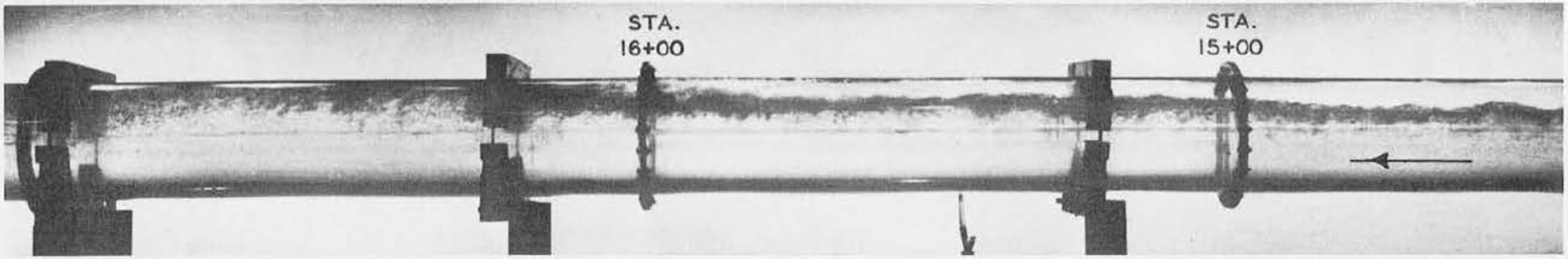


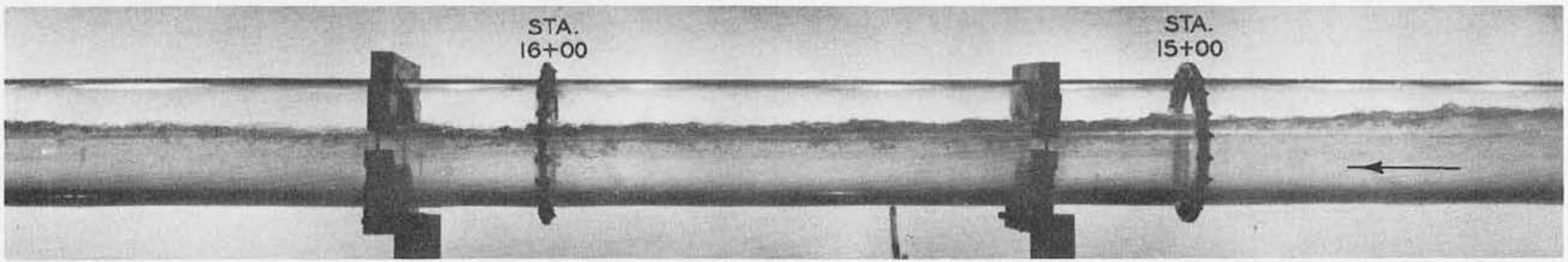
Fig. 4. Unstable jump in 80-ft drop-down at sta 8+75, all gate passages fully open (flow is from right to left). Discharge 16,000 cfs, pool elev 530.0 ft



Jump at station 14+75



Jump at station 15+75



Low surge following passage of jump at station 15+75

Fig. 5. Passage of unstable jump through conduit, three gate passages fully open
Discharge, 16,000 cfs, pool elev, 530.0 ft (flow is from right to left)

the downstream end of the division piers. The jump then moved rapidly downstream throughout the entire length of conduit, being expelled with considerable force into the stilling basin. The frequency of jump formation increased at high pool elevations and as many as five individual hydraulic jumps were present in the conduit at the same time. Operating conditions for which the undesirable jump action obtained were as follow:

Gate Operation		Range in	Range in
Center Gate	Side Gates	Pool Elevation	Discharge (cfs)
Open	Open	519 to 542	13,400 to 18,300
1/4 Open	Open	584 to 597	18,600 to 20,000
1/2 Open	Open	569 to 585	18,500 to 20,390
3/4 Open	Open	553 to 568	18,175 to 20,250
Open	3/4 Open	573 to 586	18,425 to 19,900
7/8 Open	7/8 Open	564 to 578	17,525 to 18,625

Note: The above observations were made for a rising pool. Pool elevations were 5 to 10 ft lower for falling stages before the unstable flow conditions disappeared.

16. Pressures. Pressures measured in the transition section for various operating conditions are listed in tables 1 and 2. Piezometer locations are shown on plates 8 and 9. A study of the data presented in tabular form indicates that pressures were positive for pool elevations of 578 and above for conditions with all gates open. For a pool elevation of 542, however, pressures at the top of the center and side gate passages near the downstream end of the division piers were as low as -5 ft and -7.5 ft, respectively. A pressure of -15 ft was recorded in the roof of the outside gate passage for conditions of the center gate closed and a pool elevation of 592; for conditions of only the center gate operating the maximum negative pressure recorded was -3.8. Pressures downstream from the division piers in general were positive

except for those unstable flow conditions described in the previous paragraph. The formation and downstream movement of the hydraulic jumps caused almost instantaneous pressure fluctuations within the conduit ranging from +50 ft in the vicinity of the jump to -20 ft in the area immediately upstream. The area of pressure fluctuation moved downstream with the hydraulic jump.

17. Alterations to transition of original design. An auxiliary air vent was placed at the downstream end of the division piers in the transition section (fig. 6) in an effort to eliminate or at least stabilize the hydraulic jump for the operating conditions described in paragraph 15. Tests revealed that the additional vent was beneficial only when all three gates were open full. The hydraulic jump occurred only between pool

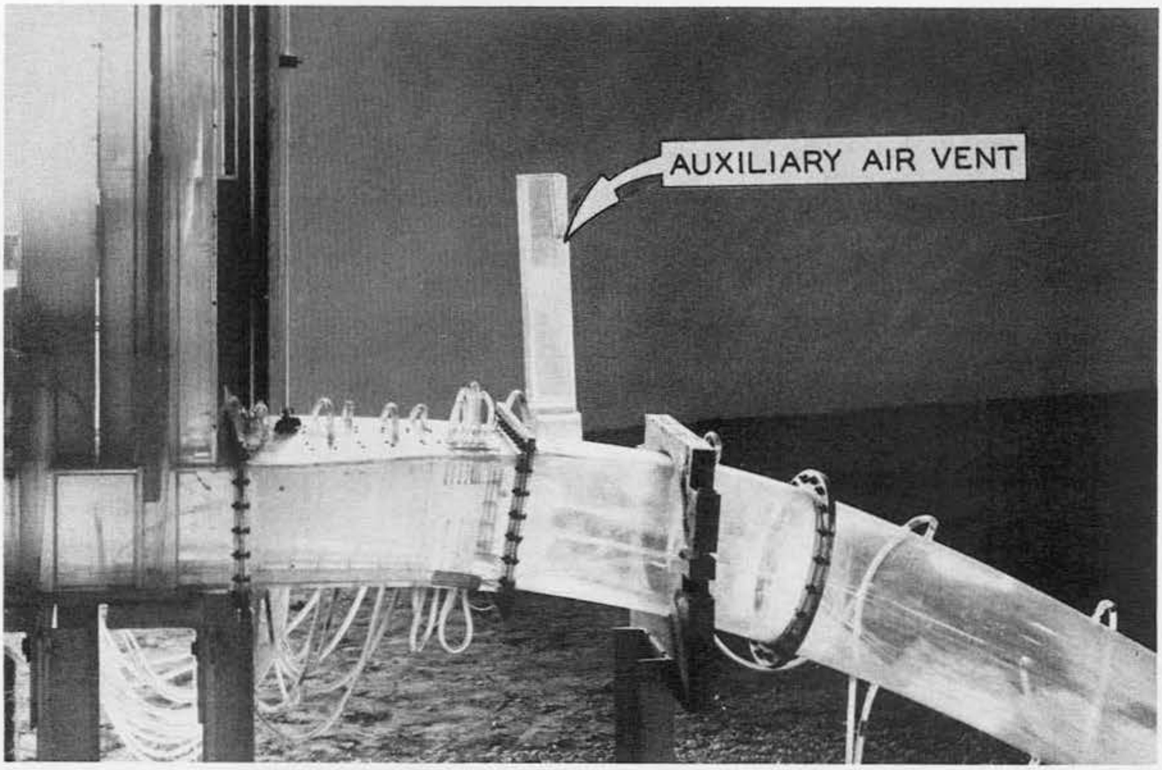


Fig. 6. Auxiliary air vent

elevations of 535 and 547 as compared to pool elevations of 519 to 542 with the vent omitted.

18. Additional revisions investigated involved longer division piers and a more gradual convergence from the rectangular section of the transition to the circular portion. The division piers were extended downstream to within 12.5 ft of the circular section and the convergence of the side walls was changed from 1 on 4 to 1 on 10 (plate 10). Tests indicated slight improvement in flow conditions but not enough to warrant the revision of the transition section. The unstable jump action was still present. Pressure data throughout the revised transition and outlet works are shown in table 3. Piezometer locations also are shown on plate 10. Comparison of pressure data for the original and revised transitions is shown in table 4.

Flood-control Conduit

Description

19. The flood-control conduit is part of a conduit used during the construction period for diversion of river flow. The diversion conduit was sealed upstream from invert elevation 400 following closure of the dam (plate 1). Upstream from this point (station 9+16.93) the flood-control conduit joins the transition section at elevation 430 by means of a vertical curve with a radius of 178.6. Downstream the conduit invert has a constant slope for a distance of about 1123 ft and terminates at elevation 399 at the junction with the stilling basin. A change in horizontal alignment of 19 degrees to the left is located about 295 ft upstream from the end of the conduit (plate 2). The alignment change is

effected by a circular curve with a radius of 399.74 ft.

Tests

20. Flow conditions. Observation of flow conditions revealed satisfactory performance for discharges in excess of 18,300 cfs. The conduit flowed full throughout its entire length for discharges greater than 20,000 cfs. As mentioned previously, unstable flow conditions existed for discharges ranging from 13,400 to 18,300 when all gates were opened full. Partial conduit flow existed for discharges less than 13,400 cfs. However, the change in horizontal alignment near the downstream end of the conduit caused a build-up of flow on the outside of the bend and unbalanced flow in the stilling basin for some discharges (photograph 5).

21. Pressures. Pressure data in the conduit for various conditions of discharge and gate operation are presented in tables 1 and 2. Pressures throughout the conduit were positive except for the condition of the unstable hydraulic jump formation described previously. The rapid change in pressure from +50 to -20 ft of water immediately before and after the jump is not conducive to good hydraulic conditions within the conduit.

22. Alterations to conduit. An effort was made to improve flow conditions for partial conduit flow by revision of the horizontal alignment upstream from the stilling basin. The simple curve of original design (radius 399.7 ft) was replaced alternately with a parabolic curve ($X^2 = 1768.14Y$), a circular curve with a radius of 682.9 ft, and a rectangular open channel with a superelevated bottom. The latter revision conformed to the alignment of original design. The open channel was 19 ft wide with a maximum superelevation of 7.35 ft.

23. Tests of the three alternate alignments indicated that the

circular curve with a radius of 682.9 ft was the most beneficial revision, although some unsymmetrical flow conditions still existed. The parabolic alignment and the open channel with superelevated bottom produced worse flow conditions, particularly for the conditions under which the outlet might be expected to operate. Photographs 1-3 show flow conditions existing in the stilling basin with each of the alternate conduit alignments investigated.

24. A few tests were conducted with a regulating gate on the end of the conduit of original alignment to secure better distribution of flow into the stilling basin and reduce the range of pool elevation and gate operating conditions at which hydraulic jump action existed in the conduit. No improvement in flow conditions was effected and the tests of the regulating gate were discontinued.

Stilling Basin

Description

25. The stilling basin of original design was of the hydraulic-jump type and consisted of a transition and sloped apron from the conduit exit to the horizontal apron, two rows of 8-ft-high baffle piers, sloped end sill 5 ft high, and diverging spray and wing walls (photograph 4 and plate 11). The sloping apron followed the trajectory of a jet ($X^2 = -695Y$) corresponding to a velocity of 1.5 times the conduit exit velocity for a discharge of 20,000 cfs. The horizontal apron was 110 ft long and was at elevation 371. This elevation is 85 per cent of the theoretical depth (elev 366) required for the formation of a hydraulic jump at 20,000 cfs.

Tests

26. Model investigations of the stilling basin involved observation of flow conditions, measurements of water-surface profiles, measurements of velocities at the end sill and in the exit channel, and determination of erosion tendencies. Tailwater rating curves are shown on plate 12. Most tests were conducted for minimum tailwater conditions.

27. Flow conditions. Unequal distribution of flow in the stilling basin was evident at certain discharge rates below 12,000 cfs because of the characteristics of conduit flow previously described. Stilling basin performance was good where full conduit flow existed or where good distribution of flow existed at the conduit exit portal. Photographs 5-8 show stilling basin action for various discharge conditions. Water-surface profile for a discharge of 15,000 cfs is shown on plate 13.

28. Scour. Erosion tests indicated that, even with unbalanced flow conditions in the stilling basin, the high velocity jet issuing from the conduit was reduced to such a degree before it entered the exit area that erosion tendencies were not considered excessive. Scour data obtained with the basin of original design and a discharge of 15,000 cfs are presented on plate 13. Areas of greatest attack were located near the wing walls immediately downstream from the end sill.

29. Bottom velocities. Bottom velocities presented on plate 13 indicate that for a discharge of 15,000 cfs, the maximum design regulated discharge, velocities in the exit channel were as high as 10.6 ft per sec. For a discharge of 21,800 cfs, maximum capacity at spillway crest level, velocities in the exit area were as high as 12.1 ft per sec.

30. Alterations to stilling basin. The sloping apron portion of the

stilling basin was stepped in an effort to improve flow distribution before the high velocity flow entered the hydraulic jump. The steps were 2 ft high and perpendicular to the side walls, meeting at a point on the longitudinal center line of the stilling basin. Although some improvement in flow distribution seemed apparent at high flows, the improvement was not sufficient at low flows to justify the cost of installation (photographs 9-10).

31. A number of baffle pier locations, end-sill types and heights, and basin widths were investigated to improve basin performance. Baffle pier height was maintained at 8 ft and apron length was maintained at 371 ft. Alterations studied are shown in tabular form below:

Stilling Basin Designs

Type Design	Basin Width (Ft)	Location of Baffle Piers Row 1	Location of Baffle Piers Row 2	End Sill* Type	End Sill* Height (Ft)
1	122	22+09.45	22+40.45	Sloped	5
2	122	-----	22+40.45	Sloped	5
3	122	22+21.00	22+52.00	Sloped	5
4	122	-----	22+52.00	Sloped	5
5	122	-----	-----	Vertical	5
6	122	-----	22+40.45	Vertical	5
7	122	22+09.45	22+40.45	Vertical	5
8	122	22+09.45	22+40.45	Vertical	7
9	122	22+09.45	22+40.45	Vertical	9
10	102	22+09.45	22+40.45	Vertical	5
11	102	22+09.45	22+40.45	Vertical	7

* End sill located at station 22+90.

32. Scour and bottom velocity measurements were made for a discharge of 15,000 cfs for each of the above stilling basin designs. Comparison of all data indicated that best over-all performance was obtained with the stilling basin designated as type 8 design. This basin was identical to the original design except that the 5-ft-high sloped end sill was

replaced with a 7-ft-high vertical end sill. Scour and bottom velocities for discharges above and below 15,000 cfs for type 8 design are presented on plates 14-17. Flow conditions are shown by photographs 11-15. Elimination of all baffle piers (type 5) did not result in excessive scour or bottom velocities but did cause increased turbulence within the stilling basin. Scour and velocity data for types 5 and 8 designs at a discharge of 15,000 cfs are shown on plates 16 and 18; flow conditions are shown on photographs 14 and 16. The unbalanced flow conditions in the stilling basin at low flows produced by the horizontal alignment of the conduit were not appreciably affected by alterations to the elements of the stilling basin. A slight improvement in flow conditions for low discharges resulted from decreasing the basin width to 102 ft. However, velocities in the exit channel were increased for high discharges.

PART IV: DISCUSSION OF RESULTS

33. The results of the model investigations indicated the desirability of modifying certain elements of the outlet works for Blakely Mountain Dam as originally designed. However, personnel of the Lower Mississippi Valley Division considered that in some instances the sacrifice of hydraulic perfection was warranted in the interests of economy. Also, some of the unsatisfactory hydraulic conditions observed can be avoided by proper manipulation of the three service gates.

34. The model verified the discharge capacity of the outlet works in that model flows were in close agreement with the computed discharges. The existence of negative pressures on the roof of the entrance curve to the intake structure and the sharp drop in pressure gradient in this area indicated the desirability of a more gradual curvature.

35. The transition and 80-ft drop from the gate section to the 19-ft-diameter circular conduit at elevation 400 resulted in the formation of an unstable hydraulic jump for certain operating conditions enumerated in paragraph 15. The hydraulic jump formed in the transition section, then moved rapidly downstream and out of the conduit. A new hydraulic jump formed in the transition section shortly after the previous one started its downstream movement. A revised transition and the use of an air vent in the transition were investigated but did not effect enough improvement in flow conditions to warrant their use. Fortunately, most of the unstable flow conditions observed occurred below minimum flood-control pool or at discharges in excess of the design maximum regulated outflow of 15,000 cfs. Thus, an operating schedule for the gates can be selected

which will preclude the unstable flow conditions. Best over-all performance for the maximum flood release of 15,000 cfs was obtained by operation of the center gate at full opening and the side gates at equal openings, the actual opening depending upon the pool elevation.

36. Unbalanced flow conditions generally existed in the stilling basin for discharges below 13,500 cfs as a result of flow piling up on the outside of the horizontal bend in the conduit. Tests indicated that an increase in the radius of the circular curve from 399.7 to 682.9 ft would provide the desired hydraulic conditions. However, it was found impractical to make this alteration in the field because of the tight construction schedule. Also, the tests indicated that no harmful erosion should occur in the prototype, even with unbalanced flow conditions in the stilling basin.

37. Tests of the stilling basin demonstrated that the original design was generally satisfactory. Modifications to the sloping apron and to the basin width failed to improve basin performance. The original arrangement of baffle piers also was indicated. Substitution of a 7-ft vertical-faced end sill for the 5-ft sloped end sill of original design effected some reduction of velocities in the exit area. This latter modification to the stilling basin was incorporated in the prototype structure. Use of an end sill in excess of 7 ft in height was not warranted.

TABLES

Table 1

PRESSURES IN GATE PASSAGE AND CONDUIT

Piez No.	Piez Station	Piez Zero Elev	Discharge, 21,800 Pool Elev, 592.0 Pressures *(1)	Discharge, 20,825 Pool Elev, 578.0 Pressures *(1)	Discharge, 18,200 Pool Elev, 542.0 Pressures *(1)
1	6+20.28	505.0	72.0	60.0	26.0
2	+20.48	503.5	63.5	51.5	20.5
3	+20.93	502.1	54.9	43.9	16.4
4	+21.63	500.8	49.2	38.2	13.7
5	+22.60	499.6	42.4	32.4	6.4
6	+23.75	498.6	37.4	27.4	2.9
7	+24.93	497.8	32.2	23.2	-1.3
8	+26.23	497.0	27.0	19.0	-4.0
9	+27.63	496.4	23.6	16.6	-4.9
10	+29.03	495.9	19.1	11.6	-7.9
11	+30.48	495.6	17.9	11.4	-8.6
12	+31.93	495.3	18.7	12.7	-6.8
13	+33.40	495.1	21.4	14.4	-6.1
14	+34.95	495.0	24.5	18.5	-3.0
15	+20.28	505.0	71.0	58.0	26.0
16	+20.48	503.5	62.5	49.5	20.5
17	+20.93	502.1	51.9	41.9	16.9
18	+21.63	500.8	49.2	38.2	14.2
19	+22.60	499.6	42.9	31.4	5.9
20	+23.75	498.6	37.4	26.4	3.9
21	+24.93	497.8	30.2	25.2	---
22	+26.23	497.0	28.0	21.0	-3.0
23	+27.63	496.4	24.6	17.6	-3.4
24	+29.03	495.9	19.6	12.6	-5.9
25	+30.48	495.6	21.4	12.9	-5.6
26	+31.93	495.3	16.2	9.7	---
27	+33.40	495.1	22.9	14.9	---
28	+34.95	495.0	---	---	---
29	+37.03	495.0	32.0	24.0	0.0
30	+48.30	495.0	36.0	25.0	2.5
31	+65.35	495.0	33.0	24.0	0.5
32	+07.45	487.5	100.5	87.5	49.0
33	+09.95	487.5	93.5	79.5	45.5
34	+12.45	487.5	89.5	75.5	41.5
35	+14.95	487.5	86.5	73.5	39.5
36	+20.28	487.5	75.5	63.5	32.5
37	+27.78	487.5	56.5	46.5	19.5
38	+48.30	487.5	45.0	36.5	10.5
39	+65.35	487.5	42.0	33.5	8.5
40	+07.45	487.5	87.5	76.5	41.5
41	+09.95	487.5	87.5	75.5	41.5
42	+12.45	487.5	83.5	73.5	39.5
43	+14.95	487.5	80.5	69.5	37.5
44	+20.28	487.5	75.5	65.5	34.5
45	+27.78	487.5	59.5	49.5	21.5
46	+48.30	487.5	46.0	36.5	12.0
47	+65.35	487.5	42.5	33.5	10.0
48	+71.85	480.0	46.0	38.0	15.0
49	+72.12	495.0	31.5	23.5	0.0
50	+79.85	479.7	38.3	31.3	9.8
51	+80.67	495.0	27.0	20.0	-2.5
52	+88.85	479.0	35.0	28.0	7.0
53	+90.34	495.0	25.0	17.5	-5.0
54	+71.85	480.0	45.0	38.0	14.5
55	+72.12	495.0	31.0	23.5	0.5
56	+83.85	479.4	30.1	23.6	4.1
57	+84.96	495.0	20.5	13.5	-7.0
58	+95.85	478.3	26.7	20.7	1.7

Notes: Piezometer locations are shown on plates 4, 8, and 9.

* Pressures are in prototype ft of water.

(1) All gates open full.

Table 1 (Continued)

Piez No.	Piez Station	Piez Zero Elev	Discharge, 21,800 Pool Elev, 592.0 Pressures *(1)	Discharge, 20,825 Pool Elev, 578.0 Pressures *(1)	Discharge, 18,200 Pool Elev, 542.0 Pressures *(1)
59	6+97.93	495.0	20.0	13.0	-7.5
60	+71.99	487.5	45.5	35.5	12.0
61	+84.41	487.2	30.3	21.8	0.8
62	+96.89	486.6	20.4	13.4	-5.1
63	7+07.31	485.4	25.6	18.6	-0.9
64	+05.85	476.8	34.2	26.2	7.2
65	+08.77	494.0	27.0	22.0	---
66	+30.85	471.2	38.8	30.8	1.8
67	+36.26	490.5	31.5	23.5	---
68	+33.55	480.8	30.2	24.7	3.2
69	6+94.60	485.0	27.0	21.0	1.0
70	+96.60	485.0	27.5	22.0	2.0
71	+98.60	485.0	---	---	---
72	7+00.40	485.0	17.0	12.0	-6.5
73	+00.90	485.0	22.0	18.0	-2.0
74	+00.75	490.0	20.0	11.5	-8.0
75	+00.75	490.0	23.0	15.0	---
76	6+99.45	490.0	25.5	17.0	-2.0
77	+97.55	490.0	28.5	18.0	---
78	+95.57	490.0	28.5	19.0	-2.5
79	+96.60	490.0	27.0	18.5	-3.5
80	+98.60	490.0	28.0	20.0	---
81	7+00.40	490.0	22.0	14.0	---
82	+65.35	480.4	29.6	22.6	2.6
83	+61.60	471.2	34.8	26.8	7.8
84	+57.85	462.0	39.0	31.0	14.0
85	+89.29	469.6	30.4	25.4	7.4
86	+84.77	460.7	37.3	29.3	12.8
87	+80.35	451.9	41.1	34.1	19.1
88	8+12.79	456.1	40.9	32.9	16.9
89	+07.82	447.8	44.2	37.2	21.2
90	+02.85	439.5	47.5	40.5	26.0
91	+37.91	439.9	30.1	25.1	14.1
92	+33.21	431.2	47.8	40.8	28.3
93	+28.50	423.4	64.1	58.1	42.6
94	+57.98	431.8	35.2	30.2	19.2
95	+54.47	421.5	55.5	50.5	36.5
96	+50.96	412.6	73.9	65.4	53.4
97	+79.21	423.7	39.3	35.3	26.3
98	+76.97	414.4	62.6	54.6	43.6
99	+74.72	405.2	81.3	74.8	59.8
100	9+01.18	419.8	47.2	43.2	26.2
101	+00.24	410.3	55.7	52.7	40.7
102	8+99.30	400.9	85.1	79.1	63.6
103	9+25.00	400.0	77.0	71.0	58.0
104	10+75.00	399.9	67.1	63.1	51.6
105	12+25.00	399.7	58.8	55.8	45.8
106	13+75.00	399.6	46.4	42.4	37.4
107	15+25.00	399.5	38.5	36.0	32.0
108	16+75.00	399.3	32.7	31.7	27.2
109	16+93.95	408.8	16.2	15.2	12.7
110	17+21.86	399.3	25.7	24.7	22.7
111	17+21.86	408.8	22.2	21.2	17.2
112	17+49.76	408.8	09.2	09.2	7.7
113	17+77.68	399.2	24.8	23.8	21.8
114	+77.73	408.7	17.3	17.3	14.3
115	18+05.58	408.7	09.3	08.8	7.8
116	+50.06	399.2	19.8	19.8	18.3
117	20+00.00	399.0	13.0	13.0	13.0

Notes: Piezometer locations are shown on plates 4, 8, and 9.

* Pressures are in prototype ft of water.

(1) All gates open full.

Table 2

PRESSURES IN GATE PASSAGE AND CONDUIT

Piez No.	Piez Station	Piez Zero Elev	Discharge, 17,400 Pool Elev, 592.0 Pressures *(2)	Discharge, 16,000 Pool Elev, 578.0 Pressures *(2)	Discharge, 8,650 Pool Elev, 592.0 Pressures *(3)	Discharge, 8,050 Pool Elev, 578.0 Pressures *(3)
1	6+20.28	505.0			71.0	60.0
2	+20.48	503.5			59.5	50.5
3	+20.93	502.1			47.9	39.9
4	+21.63	500.8			39.2	31.7
5	+22.60	499.6			26.4	21.4
6	+23.75	498.6			17.4	13.4
7	+24.93	497.8			10.2	7.2
8	+26.23	497.0			2.5	2.0
9	+27.63	496.4			-2.9	-3.4
10	+29.03	495.0			-10.9	-10.4
11	+30.48	495.6			-12.6	-11.1
12	+31.93	495.3			-10.8	-10.3
13	+33.40	495.1			-8.1	-8.1
14	+34.95	495.0			-3.0	-3.0
15	+20.28	505.0			70.0	38.0
16	+20.48	503.5			59.0	49.5
17	+20.93	502.1			45.9	38.9
18	+21.63	500.8			37.2	31.7
19	+22.60	499.6			25.4	20.9
20	+23.75	498.6			17.4	13.9
21	+24.93	497.8	Gate passage closed	Gate passage closed	8.7	7.7
22	+26.23	497.0			4.0	2.5
23	+27.63	496.4			-1.4	-2.4
24	+29.03	495.9			-9.4	-8.9
25	+30.48	495.6			-7.6	-6.6
26	+31.93	495.3			---	---
27	+33.40	495.1			---	---
28	+34.95	495.0			---	---
29	+37.03	495.0			4.0	3.0
30	+48.30	495.0			10.5	8.0
31	+65.35	495.0			6.0	5.0
32	+07.45	487.5			92.5	71.5
33	+09.95	487.5			83.5	70.5
34	+12.45	487.5			79.0	66.5
35	+14.95	487.5			75.5	63.5
36	+20.28	487.5			60.0	52.5
37	+27.78	487.5			35.5	30.5
38	+48.30	487.5			20.0	17.5
39	+65.35	487.5			15.5	13.5
40	+07.45	487.5	84.5	74.5		
41	+09.95	487.5	81.5	69.5		
42	+12.45	487.5	75.5	64.5		
43	+14.95	487.5	71.5	58.5		
44	+20.28	487.5	62.5	52.5	Gate passage closed	Gate passage closed
45	+27.78	487.5	38.5	34.5		
46	+48.30	487.5	19.5	17.5		
47	+65.35	487.5	15.5	12.5		
48	+71.85	480.0	---	---	20.0	18.0
49	+72.12	495.0	---	---	5.5	4.0
50	+79.85	479.7	---	---	10.3	10.3
51	+80.67	495.0	---	---	0.0	-1.0
52	+88.85	479.0	---	---	4.5	5.0
53	+90.34	495.0	---	---	-3.0	-3.0
54	+71.85	480.0	16.0	16.0		
55	+72.12	495.0	2.5	1.5		
56	+83.85	479.4	-6.4	-3.4		
57	+84.96	495.0	-14.0	-11.5		
58	+95.85	478.3	-12.3	-8.3	Gate passage closed	Gate passage closed

Notes: Piezometer locations shown on plates 4, 8, and 9.

* Pressures are in prototype ft of water.

(2) Center gate closed, 2 side gates open full.

(3) Center gate open full, 2 side gates closed.

Table 2 (Continued)

Piez No.	Piez Station	Piez Zero Elev	Discharge, 17,400 Pool Elev, 592.0 Pressures *(2)	Discharge, 16,000 Pool Elev, 578.0 Pressures *(2)	Discharge, 8,650 Pool Elev, 592.0 Pressures *(3)	Discharge, 8,050 Pool Elev, 578.0 Pressures *(3)
59	6+97.93	495.0	-15.0	-13.0	Gate passage closed	Gate passage closed
60	+71.99	487.5	21.0	17.5		
61	+84.41	487.2	---	-1.2		
62	+96.89	486.6	---	---		
63	7+07.31	485.4	---	---	---	---
64	+05.85	476.8	-1.8	0.2	-4.8	-3.8
65	+08.77	494.0	---	---	---	---
66	+30.85	471.2	-1.2	2.8	1.8	1.8
67	+36.26	490.5	---	---	---	---
68	+33.55	480.8	---	---	---	---
69	6+94.60	485.0	1.0	3.0		
70	+96.60	485.0	3.0	4.0		
71	+98.60	485.0	---	---	Gate passage closed	Gate passage closed
72	7+00.40	485.0	-7.0	-6.0		
73	+00.90	485.0	---	---		
74	+00.75	490.0	---	---		
75	+00.75	490.0	---	---		
76	6+99.45	490.0	-2.0	-1.0		
77	+97.55	490.0	---	2.0		
78	+95.57	490.0	-3.0	3.0		
79	+96.60	490.0	---	---	---	---
80	+98.60	490.0	---	---	---	---
81	7+00.40	490.0	---	---	---	---
82	+65.35	480.4	---	---	---	---
83	+61.60	471.2	---	1.8	---	---
84	+57.85	462.0	4.5	6.0	1.0	2.0
85	+89.29	469.6	---	---	---	---
86	+84.77	460.7	---	---	---	---
87	+80.35	451.9	6.1	3.1	-0.9	0.1
88	8+12.79	456.1	---	---	---	---
89	+07.82	447.8	10.2	2.7	---	---
90	+02.85	439.5	7.5	5.5	1.5	2.0
91	+37.91	439.9	---	---	---	---
92	+33.21	431.2	6.8	---	---	---
93	+28.50	423.4	27.6	22.6	11.6	16.6
94	+57.98	431.8	---	---	---	---
95	+54.47	421.5	9.5	5.5	---	---
96	+50.96	412.6	33.4	26.9	16.4	15.4
97	+79.21	423.7	---	---	---	---
98	+76.97	414.4	15.1	---	---	---
99	+74.72	405.2	34.8	28.8	17.8	17.8
100	9+01.18	419.8	---	---	---	---
101	+00.24	410.3	---	---	---	---
102	8+99.30	400.9	31.1	29.1	14.1	19.1
103	9+25.00	400.0	23.5	15.0	12.0	8.5
104	10+75.00	399.9	16.6	14.1	9.1	8.6
105	12+25.00	399.7	18.3	12.3	8.8	7.8
106	13+75.00	399.6	15.4	10.4	7.4	6.4
107	15+25.00	399.5	15.5	11.5	6.5	6.3
108	16+75.00	399.3	18.7	14.7	9.7	8.7
109	16+93.95	408.8	9.2	4.2	---	---
110	17+21.86	399.3	17.2	14.7	8.7	8.7
111	17+21.86	408.8	14.7	11.2	---	---
112	17+49.76	408.8	4.2	1.2	---	---
113	17+77.68	399.2	16.8	15.3	9.8	8.8
114	+77.73	408.7	6.8	9.3	4.8	---
115	18+05.58	408.7	---	---	---	---
116	+50.06	399.2	16.8	15.3	10.3	11.3
117	20+00.00	399.0	16.0	15.0	10.0	9.0

Notes: Piezometer locations shown on plates 4, 8, and 9.

* Pressures are in prototype ft of water.

(2) Center gate closed, 2 side gates open full.

(3) Center gate open full, 2 side gates closed.

Table 3

PRESSURES IN REVISED TRANSITION

Piez No.	Piez Station	Piez Zero Elev	Discharge, 21,800 Pool Elev, 592.0 Pressures*(1)	Discharge, 20,825 Pool Elev, 578.0 Pressures*(1)	Discharge, 18,200 Pool Elev, 542.0 Pressures*(1)	Discharge, 17,400 Pool Elev, 592.0 Pressures*(2)	Discharge, 16,000 Pool Elev, 578.0 Pressures*(2)	Discharge, 8,650 Pool Elev, 592.0 Pressures*(3)	Discharge, 8,050 Pool Elev, 578.0 Pressures*(3)
118	6+72.12	495.0	32.5	24.0	-			---	---
119	+71.85	480.0	45.0	36.0	14.0			11.5	11.0
120	+80.67	495.0	31.0	22.5	-			---	---
121	+79.85	479.7	43.3	34.3	12.3			8.3	8.3
122	+90.34	495.0	31.0	22.0	-			---	---
123	+88.85	479.0	41.0	33.0	11.5			5.0	5.5
124	7+02.06	494.8	32.2	23.2	-	Gate passage closed	Gate passage closed	---	---
125	6+99.65	477.8	41.2	33.2	12.2			4.2	5.2
126	7+14.87	493.4	27.6	18.6	-			---	---
127	+11.10	475.9	40.6	32.6	12.1			1.6	3.1
128	+24.10	492.4	25.6	16.6	-			---	---
129	+19.85	474.0	39.0	31.5	11.0			-2.5	-1.0
130	+36.26	490.5	38.5	29.0	-			---	---
131	+30.85	471.2	41.8	34.8	12.8			-4.2	-3.2
132	+47.17	488.2	32.8	23.8	-	---	---	---	---
133	+40.85	468.8	38.2	31.2	11.2	-0.8	-2.8	-1.8	+0.7
134	6+72.12	495.0	35.0	25.0	1.5	3.0	1.0		
135	+71.85	480.0	49.0	41.0	16.0	16.5	15.0		
136	+80.67	495.0	33.0	23.0	0.0	-0.5	-1.0	Gate passage closed	Gate passage closed
137	+79.85	479.7	45.3	37.3	12.8	10.8	10.3		
138	+90.34	495.0	30.0	21.0	-2.0	-4.5	-5.0		
139	+88.85	479.0	41.0	33.0	10.5	3.0	3.0		
140	7+02.06	494.8	31.2	21.7	-1.8	-3.8	-3.8		
141	6+99.65	477.8	44.2	35.7	12.2	6.7	5.7		
142	7+14.87	493.4	31.6	21.1	-1.4	-3.4	-3.9		
143	+11.10	475.9	41.1	33.1	10.6	1.1	1.6		
144	+24.10	491.6	26.4	15.9	-4.6	-11.6	-10.6		
145	+19.85	474.7	32.8	23.8	4.8	-12.7	-10.7		
146	+36.26	488.7	38.8	28.8	0.8	-1.7	-1.7		
147	+30.85	472.9	38.1	30.1	2.6	-10.9	-9.4		
148	6+80.26	487.4	38.6	29.1	7.1	Closed	Closed	5.6	5.1
149	7+00.85	486.3	36.2	26.7	5.7	Closed	Closed	1.2	1.2
150	+16.73	484.0	34.5	25.0	5.5	Closed	Closed	-4.0	-3.0
151	6+80.26	487.4	41.6	32.6	6.6	8.6	7.1		
152	7+00.85	486.3	37.7	29.2	5.7	1.7	1.2	Gate passage closed	Gate passage closed
153	+16.73	484.0	34.0	26.0	4.0	-3.0	-2.5		
154	+44.01	478.5	28.5	21.0	-0.5	-11.5	-9.5	---	---
155	6+89.60	487.0	35.0	25.0	3.0	-2.0	-2.0		
156	7+07.31	485.4	34.6	24.6	2.6	-3.4	-2.4	Gate passage closed	Gate passage closed
157	+21.97	483.2	32.3	23.3	1.3	-7.7	-5.7		
158	+30.60	481.2	36.8	27.8	-	---	---		
159	+30.60	481.2	30.8	23.8	-	Gate passage closed	Gate passage closed	---	---

Notes: Piezometer locations are shown on plate 10.

* Pressures are in prototype ft of water.

(1) All gates open full.

(2) Center gate closed, 2 side gates open full.

(3) Center gate open full, 2 side gates closed.

Table 4

PRESSURES IN GATE PASSAGE AND TRANSITION
WITH ORIGINAL AND REVISED TRANSITION INSTALLED

Center Passage Open, Two Outside Passages One-half Open
Discharge 15,000 cfs, Pool Elev 580.0

Piez No.	Piez Station	Piez Zero Elev	Original Transition Pressure*	Revised Transition Pressure*
1	6+20.28	505.0	58.0	56.0
2	+20.48	503.5	-	-
3	+20.93	502.1	37.9	33.9
4	+21.63	500.8	31.2	25.7
5	+22.60	499.6	21.4	16.4
6	+23.75	498.6	13.4	13.4
7	+24.93	497.8	7.7	3.2
8	+26.23	497.0	1.5	-3.5
9	+27.63	496.4	-3.4	-6.4
10	+29.03	495.9	-9.9	-13.9
11	+30.48	495.6	-11.1	-14.6
12	+31.93	495.3	-9.8	-13.3
13	+33.40	495.1	-7.1	-11.6
14	+34.95	495.0	-2.0	-5.0
15	+20.28	505.0	57.5	56.0
16	+20.48	503.5	49.5	44.5
17	+20.93	502.1	39.9	33.9
18	+21.63	500.8	32.2	27.2
19	+22.60	499.6	18.9	16.4
20	+23.75	498.6	13.9	13.4
21	+24.93	497.8	6.2	-
22	+26.23	497.0	2.5	-2.0
23	+27.63	496.4	-2.9	-3.9
24	+29.03	495.9	-9.4	-12.9
25	+30.48	495.6	-7.6	-11.6
26	+31.93	495.3	-	-
27	+33.40	495.1	-	-
28	+34.95	495.0	-	-
29	+37.03	495.0	4.0	-1.0
30	+48.30	495.0	9.0	-
31	+65.35	495.0	5.0	-
32	+07.45	487.5	75.5	75.5
33	+09.95	487.5	75.0	73.0
34	+12.45	487.5	71.0	67.0
35	+14.95	487.5	72.5	62.5
36	+20.28	487.5	53.0	52.0
37	+27.78	487.5	30.5	29.5
38	+48.30	487.5	17.5	13.5

Piezometer locations are shown on plates 4, 8, 9, and 10.
* Pressures are in prototype ft of water.

Table 4 (Continued)

Piez No.	Piez Station	Piez Zero Elev	Original Transition Pressure*	Revised Transition Pressure*
39	6+65.35	487.5	13.5	5.5
40	+07.45	487.5	86.5	85.5
41	+09.95	487.5	87.5	85.5
42	+12.45	487.5	88.0	85.5
43	+14.95	487.5	86.5	85.5
44	+20.28	487.5	79.5	84.5
45	+27.78	487.5	79.0	81.5
46	+48.30	487.5	74.5	77.0
47	+65.35	487.5	-	-
48	+71.85	480.0	19.0	Numbers
49	+72.12	495.0	4.0	48-81 were
50	+79.85	479.7	-2.5	not in the
51	+80.67	495.0	-0.5	revised
52	+88.85	479.0	-10.5	transition
53	+90.34	495.0	-4.0	
54	+71.85	480.0	9.0	
55	+72.12	495.0	-	
56	+83.85	479.4	1.1	
57	+84.96	495.0	-	
58	+95.85	478.3	-1.3	
59	+97.93	495.0	-	
60	+71.99	487.5	-	
61	+84.41	487.2	-	
62	+96.89	486.6	-	
63	7+07.31	485.4	-	
64	+05.85	476.8	2.2	
65	+08.77	494.0	-	
66	+30.85	471.2	-	
67	+36.26	490.5	-	
68	+33.55	480.8	-	
69	6+94.60	485.0	-	
70	+96.60	485.0	-	
71	+98.60	485.0	-	
72	7+00.40	485.0	-	
73	+00.90	485.0	-	
74	+00.75	490.0	-	
75	+00.75	490.0	-	
76	6+99.45	490.0	-	
77	+97.55	490.0	-	
78	+95.57	490.0	-	
79	+96.60	490.0	--	
80	+98.60	490.0	-	
81	7+00.40	490.0	-	

Piezometer locations are shown on plates 4, 8, 9, and 10.

* Pressures are in prototype ft of water.

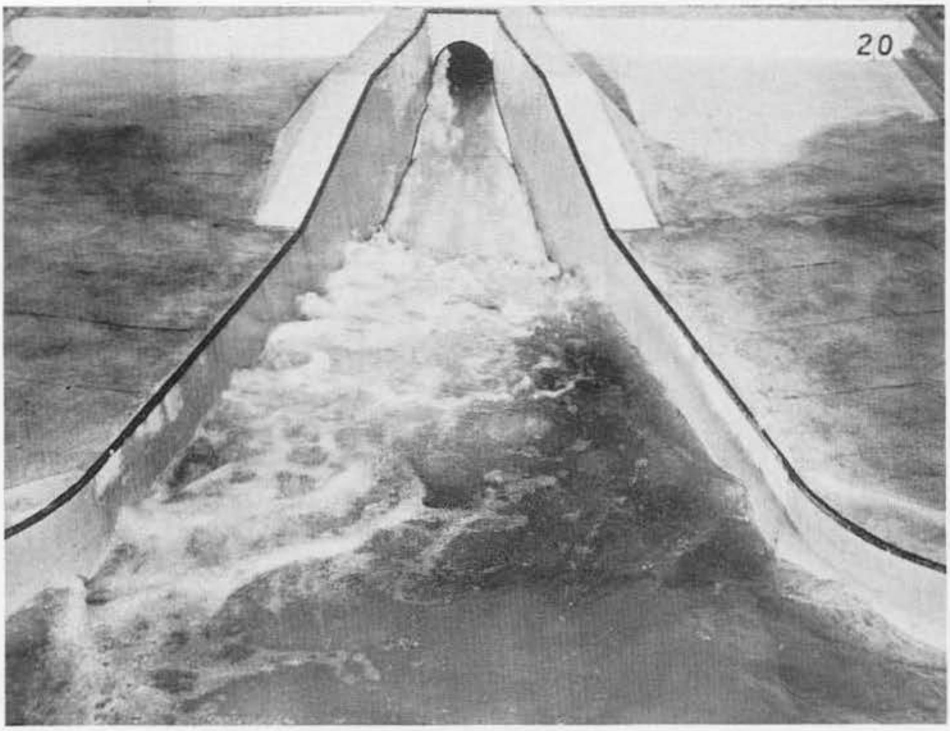
Table 4 (Continued)

Piez No.	Piez Station	Piez Zero Elev	Original Transition Pressure*	Revised Transition Pressure*
118	6+72.12	495.0	Numbers	-
119	+71.85	480.0	118-159 were	11.0
120	+80.67	495.0	not in the	-
121	+79.85	479.7	original	8.3
122	+90.34	495.0	transition	-
123	+88.85	479.0		6.0
124	7+02.06	494.8		-
125	6+99.65	477.8		5.2
126	7+14.87	493.3		-
127	+11.10	475.9		3.1
128	+24.10	492.4		-
129	+19.85	474.0		0.0
130	+36.26	490.5		-
131	+30.85	471.2		2.3
132	+47.17	488.2		-
133	+40.85	468.8		1.7
134	6+72.12	495.0		-
135	+71.85	480.0		6.5
136	+80.67	495.0		-
137	+79.85	479.7		3.8
138	+90.34	495.0		-
139	+88.85	479.0		2.0
140	7+02.06	494.8		-
141	6+99.65	477.8		8.2
142	7+14.87	493.4		-
143	+11.10	475.9		5.6
144	+24.10	491.6		-
145	+19.85	474.7		-1.2
146	+36.26	488.7		-
147	+30.85	472.9		-1.9
148	6+80.26	487.4		5.6
149	7+00.85	486.3		1.7
150	+16.73	484.0		-3.0
151	6+80.26	487.4		-
152	7+00.85	486.3		1.7
153	+16.73	484.0		2.0
154	+44.01	478.5		-
155	6+89.60	487.0		-
156	7+07.31	485.4		-
157	+21.97	483.2		-
158	+30.60	481.2		-
159	+30.60	481.2		-

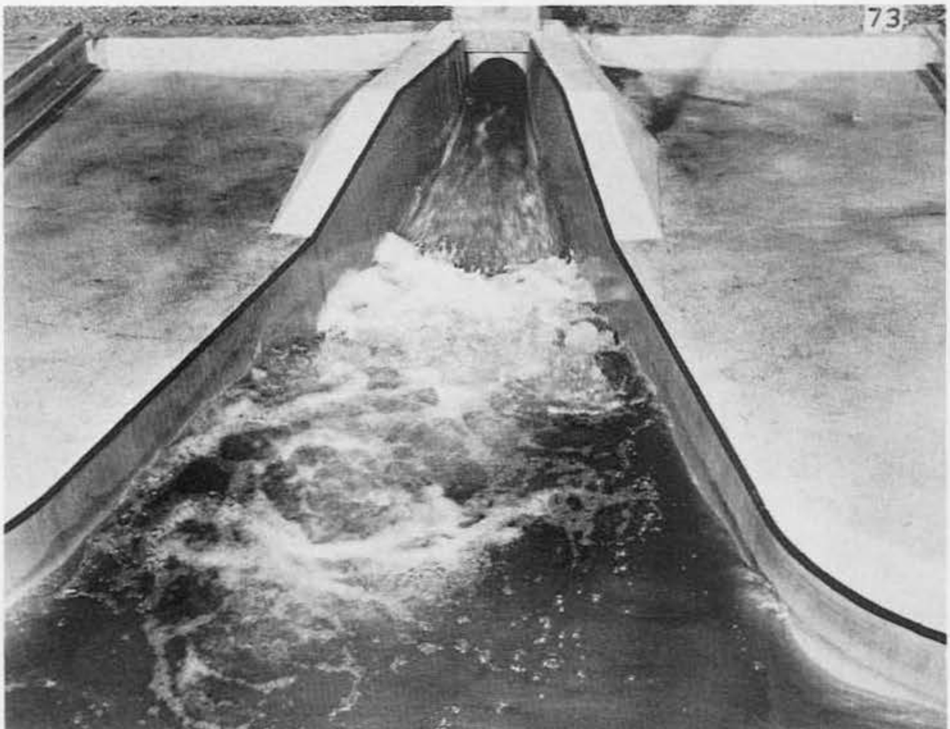
Piezometer locations are shown on plates 4, 8, 9, and 10.

* Pressures are in prototype ft of water.

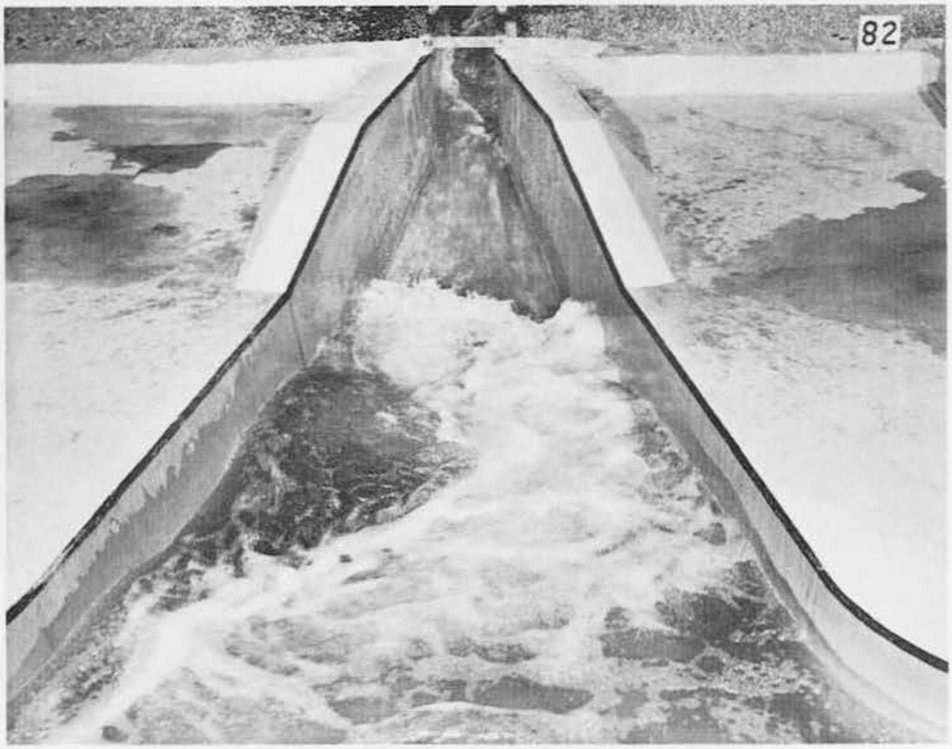
PHOTOGRAPHS



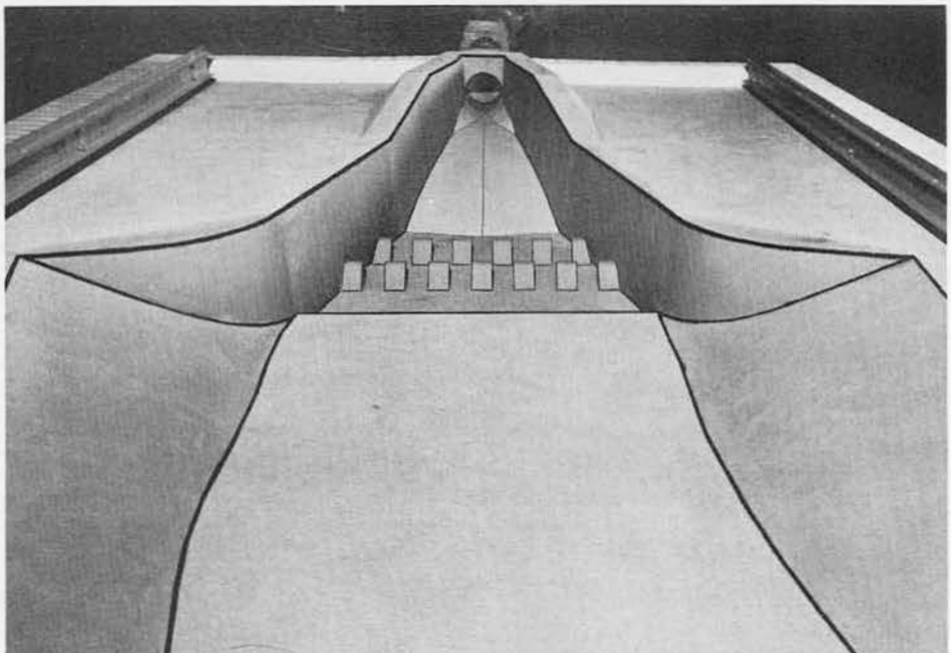
Photograph 1. Discharge, 8,650 cfs; pool elev, 592.0; TW elev, 396.0
Flow in stilling basin, parabolic curved conduit,
center gate open only



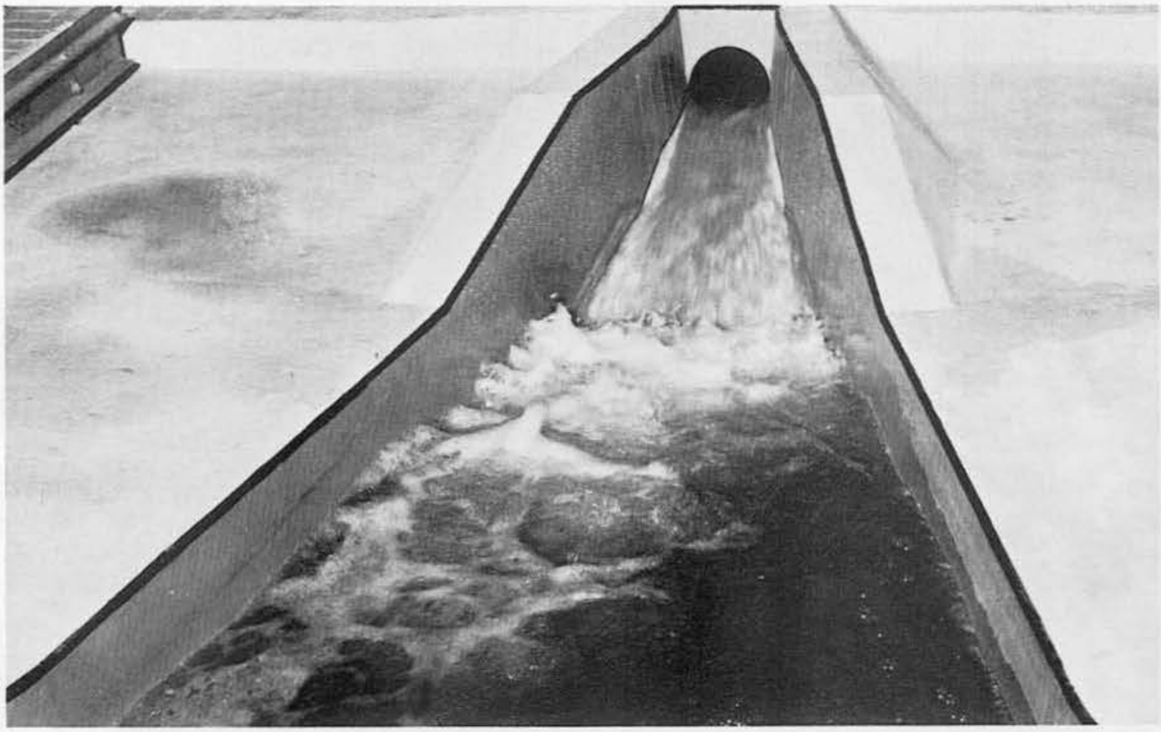
Photograph 2. Discharge, 8,650 cfs; pool elev, 592.0; TW elev, 396.0
Flow in stilling basin, 682.96-ft-radius curved conduit,
center gate open only



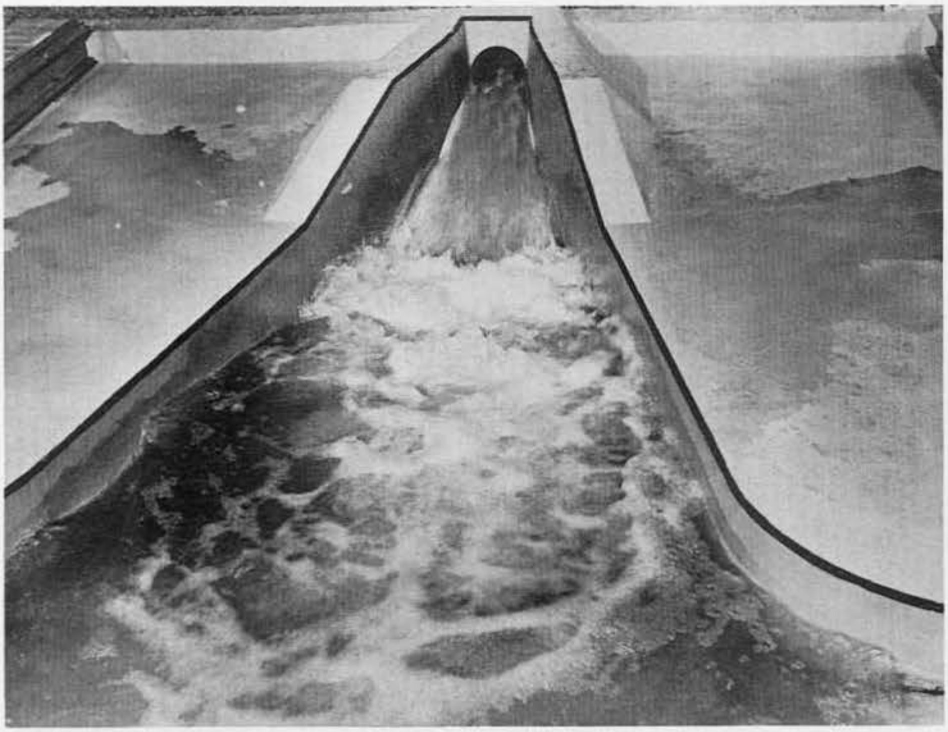
Photograph 3. Discharge, 8,650 cfs; pool elev, 592.0; TW elev, 396.0
Flow in stilling basin, open rectangular channel with super-elevated floor in conduit, center gate open only



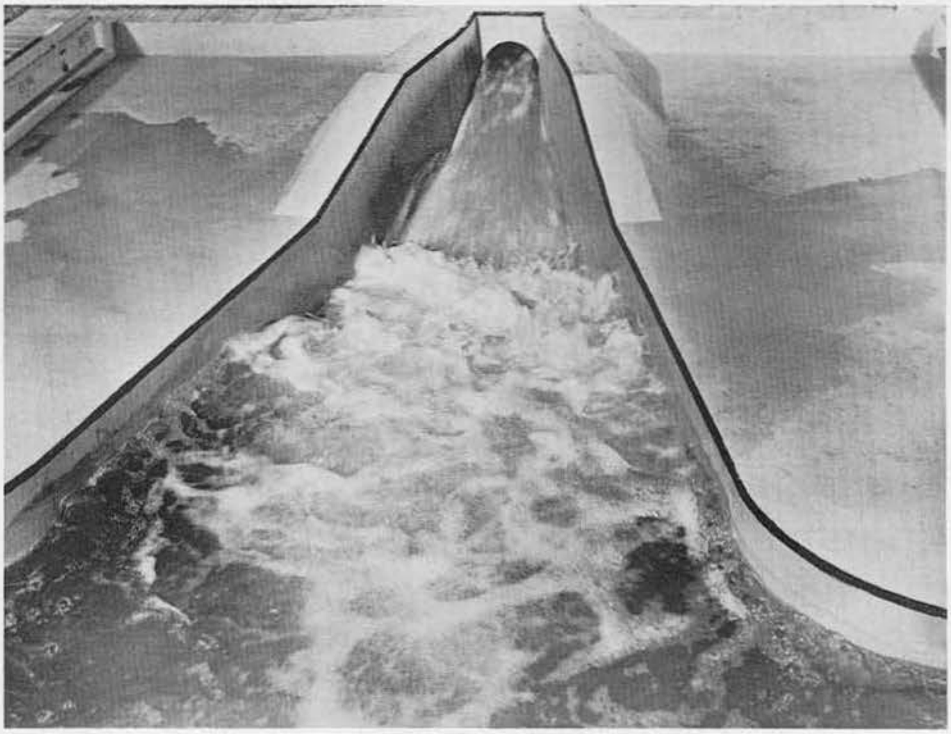
Photograph 4. Stilling basin, original design



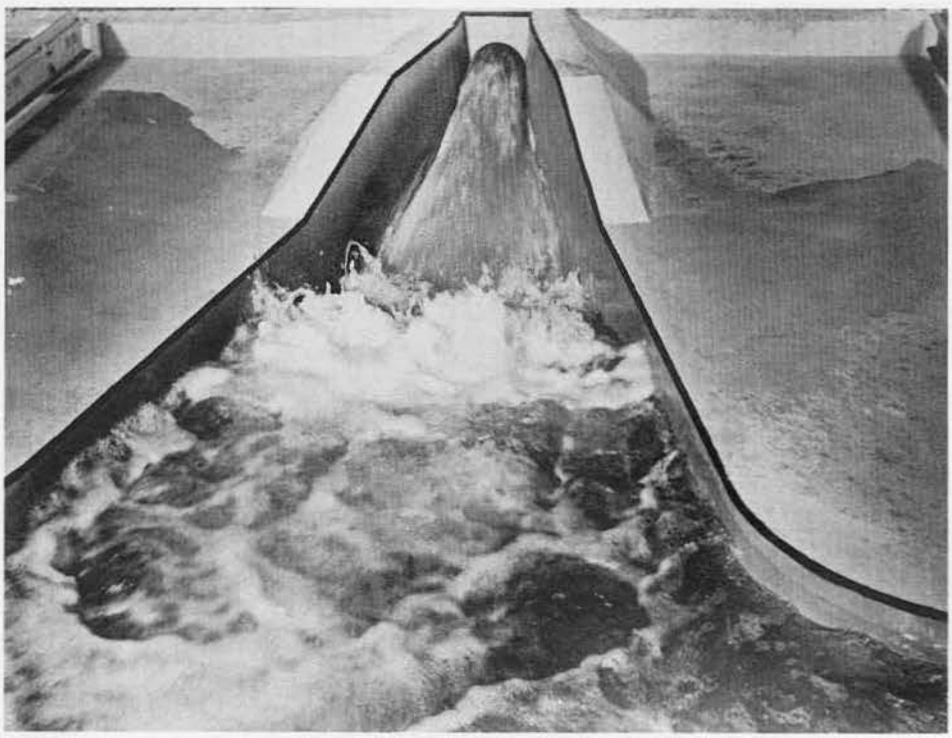
Photograph 5. Discharge, 6,900 cfs; pool elev, 554.0; TW elev, 395.2
Flow in stilling basin, original design, center gate
open, side gates closed



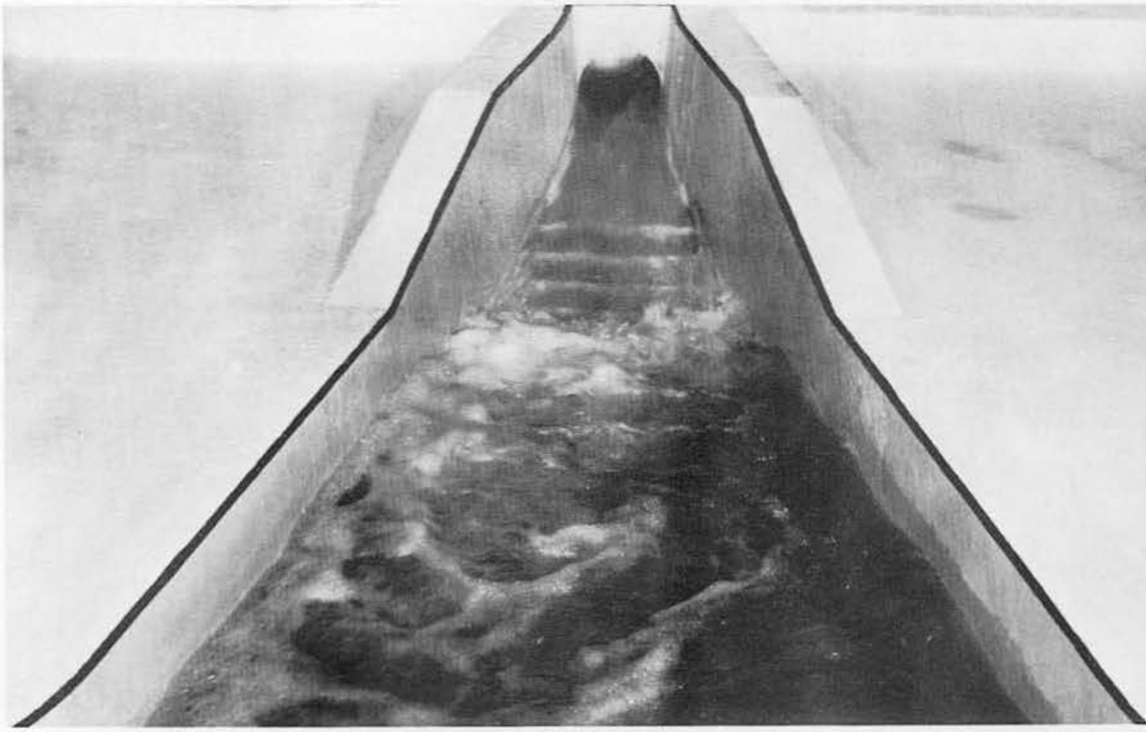
Photograph 6. Discharge, 12,500 cfs; pool elev, 592.0; TW elev, 398.0
Flow in stilling basin, original design, center gate
open, side gates 1/4 open



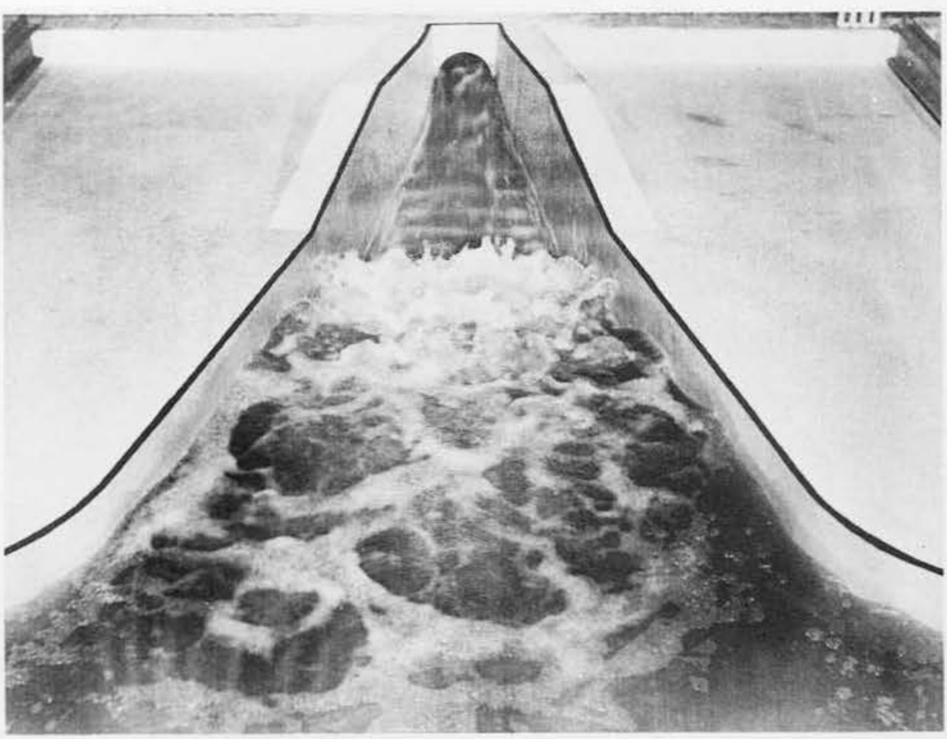
Photograph 7. Discharge, 15,000 cfs; pool elev, 580.0; TW elev, 399.0
Flow in stilling basin, original design, center gate
open, side gates 1/2 open



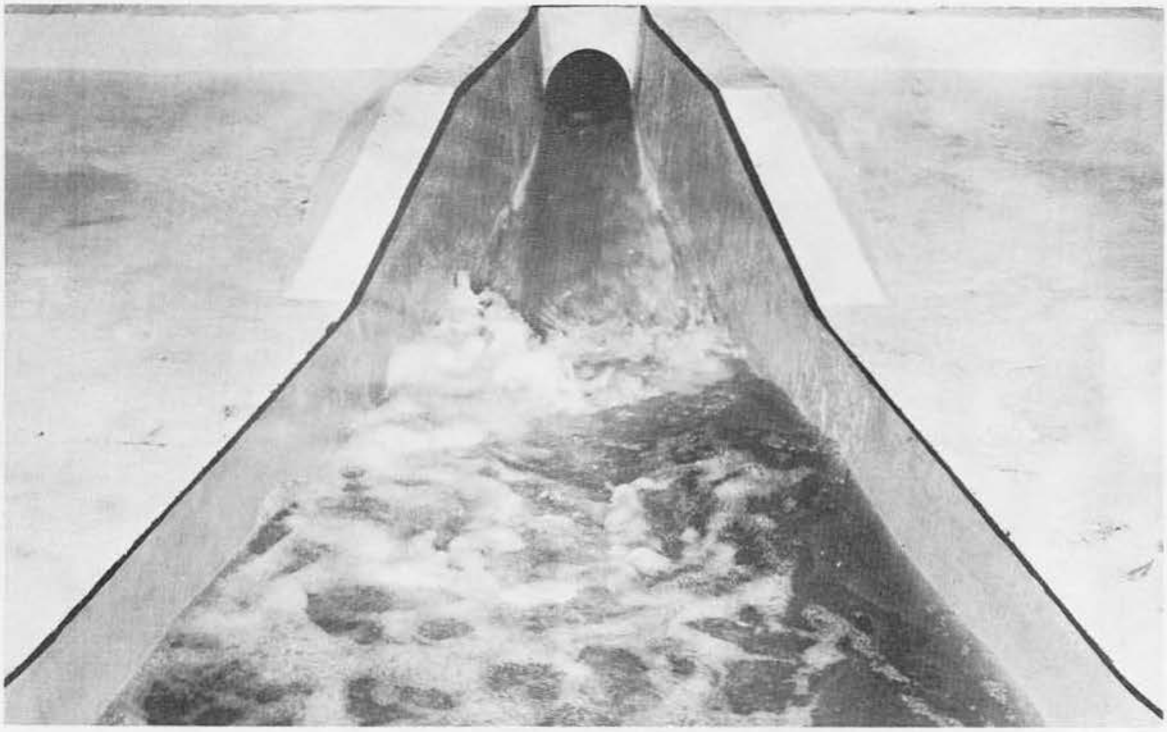
Photograph 8. Discharge, 21,800 cfs; pool elev, 592.0; TW elev, 401.6
Flow in stilling basin, original design, all gates open



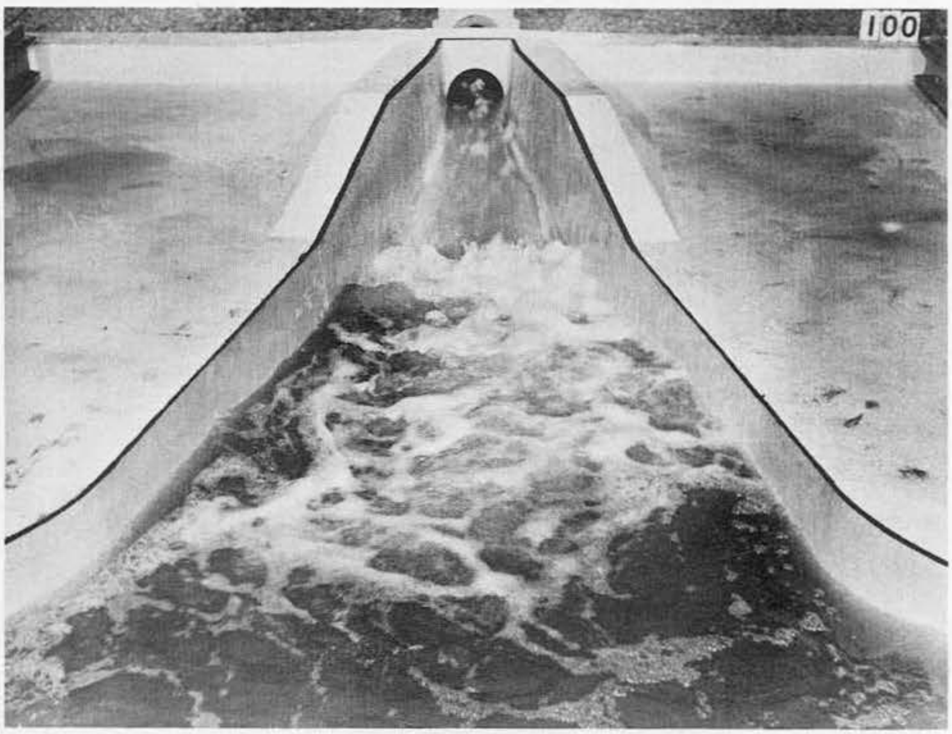
Photograph 9. Discharge, 6,900 cfs; pool elev, 554.0; TW elev, 395.2
Stepped transition, note air pockets on steps



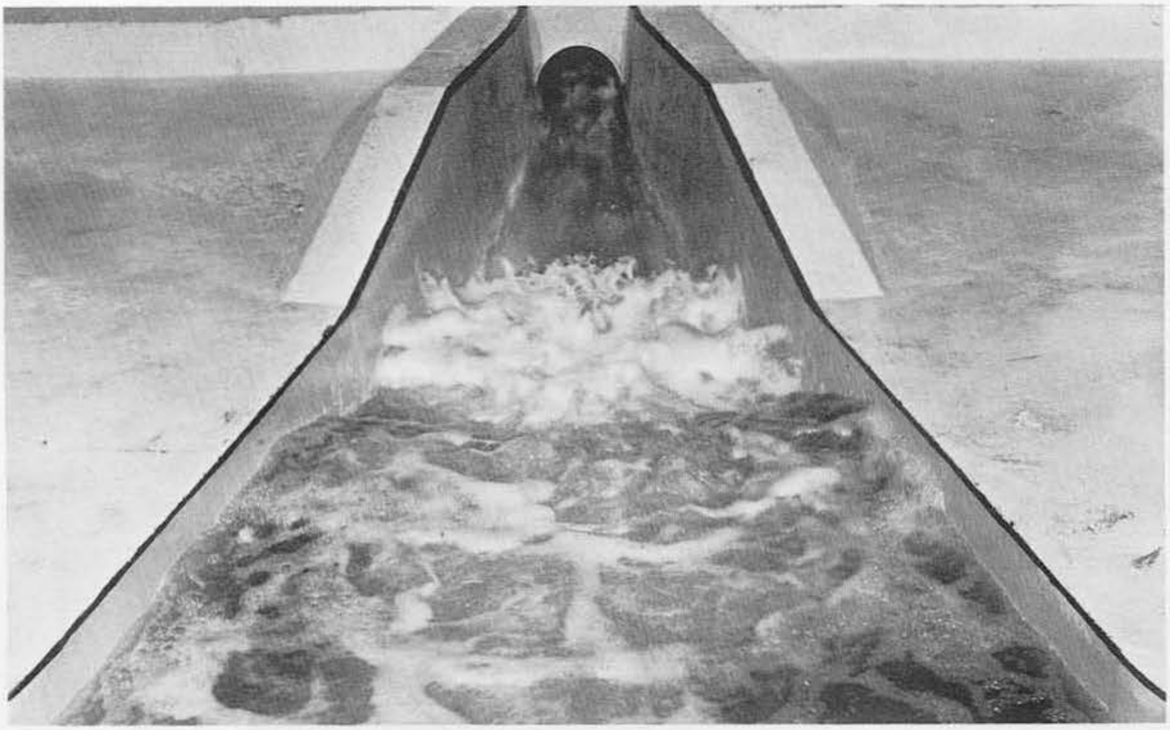
Photograph 10. Discharge, 15,000 cfs; pool elev, 580.0; TW elev, 399.0
Stepped transition, note air pockets on steps



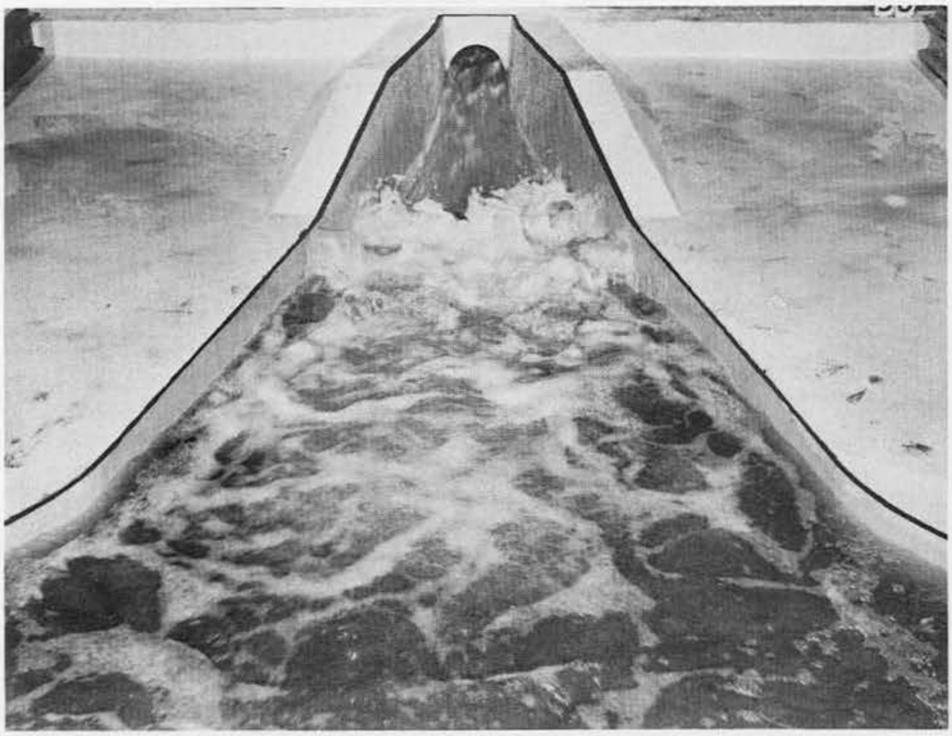
Photograph 11. Discharge, 6,900 cfs; pool elev, 554.0; TW elev, 395.2
Flow in stilling basin, type 8 design, center gate
open, side gates closed



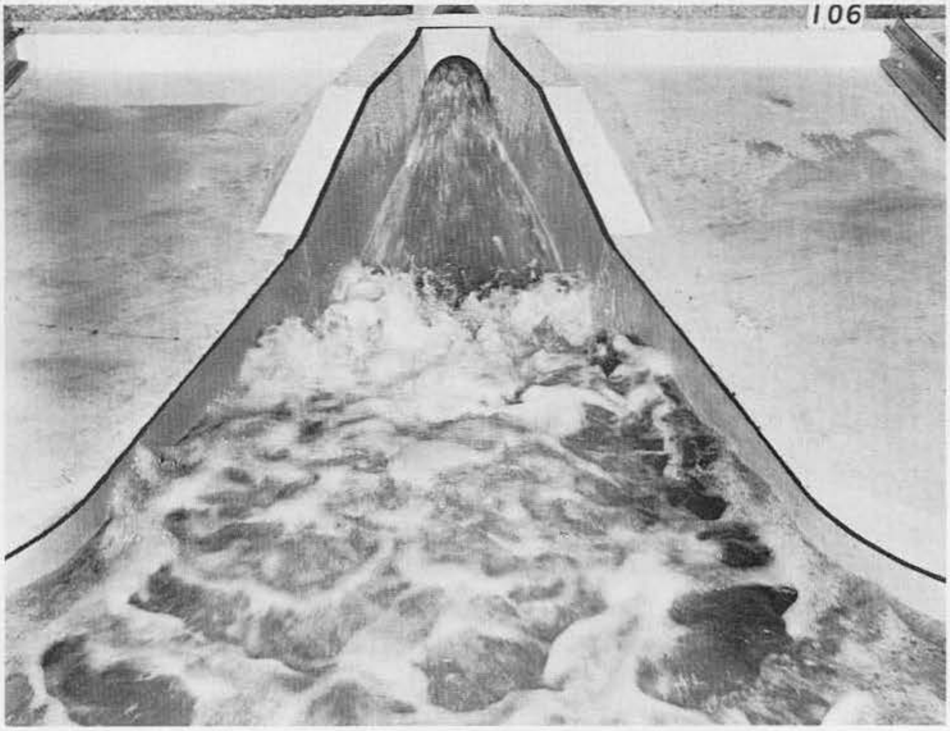
Photograph 12. Discharge, 8,650 cfs; pool elev, 592.0; TW elev, 396.0
Flow in stilling basin, type 8 design, center gate
open, side gates closed



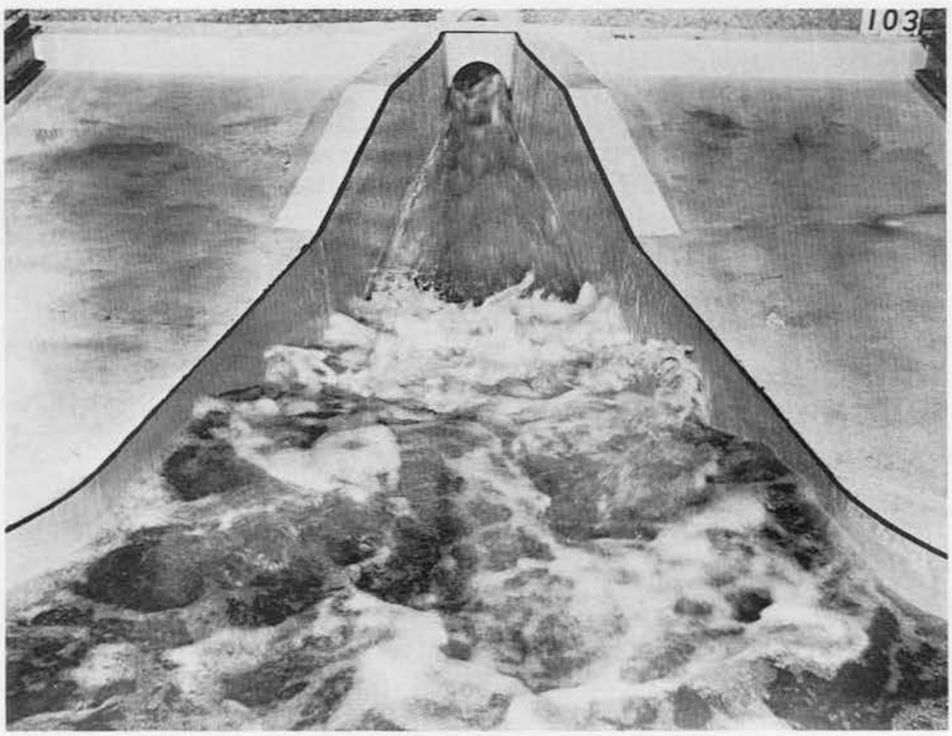
Photograph 13. Discharge, 12,500 cfs; pool elev, 592.0; TW elev, 398.0
Flow in stilling basin, type 8 design, center gate
open, side gates 1/4 open



Photograph 14. Discharge, 15,000 cfs; pool elev, 580.0; TW elev, 399.0
Flow in stilling basin, type 8 design, center gate
open, side gates 1/2 open

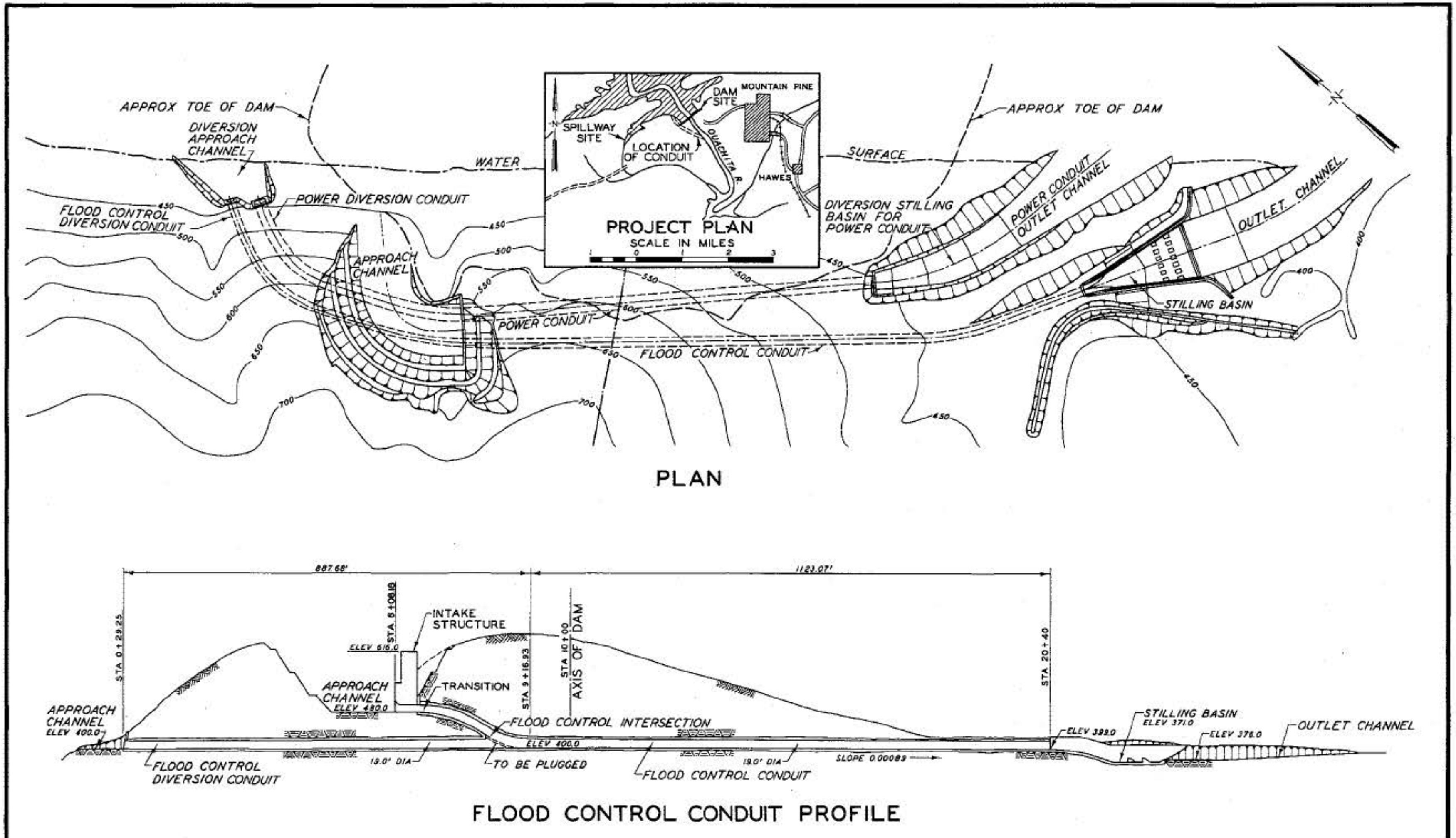


Photograph 15. Discharge, 21,800 cfs; pool elev, 592.0; TW elev, 401.6
Flow in stilling basin, type 8 design, all gates open



Photograph 16. Discharge, 15,000 cfs; pool elev, 580.0; TW elev, 399.0
Flow in stilling basin, type 5 design, both rows of baffles removed

PLATES



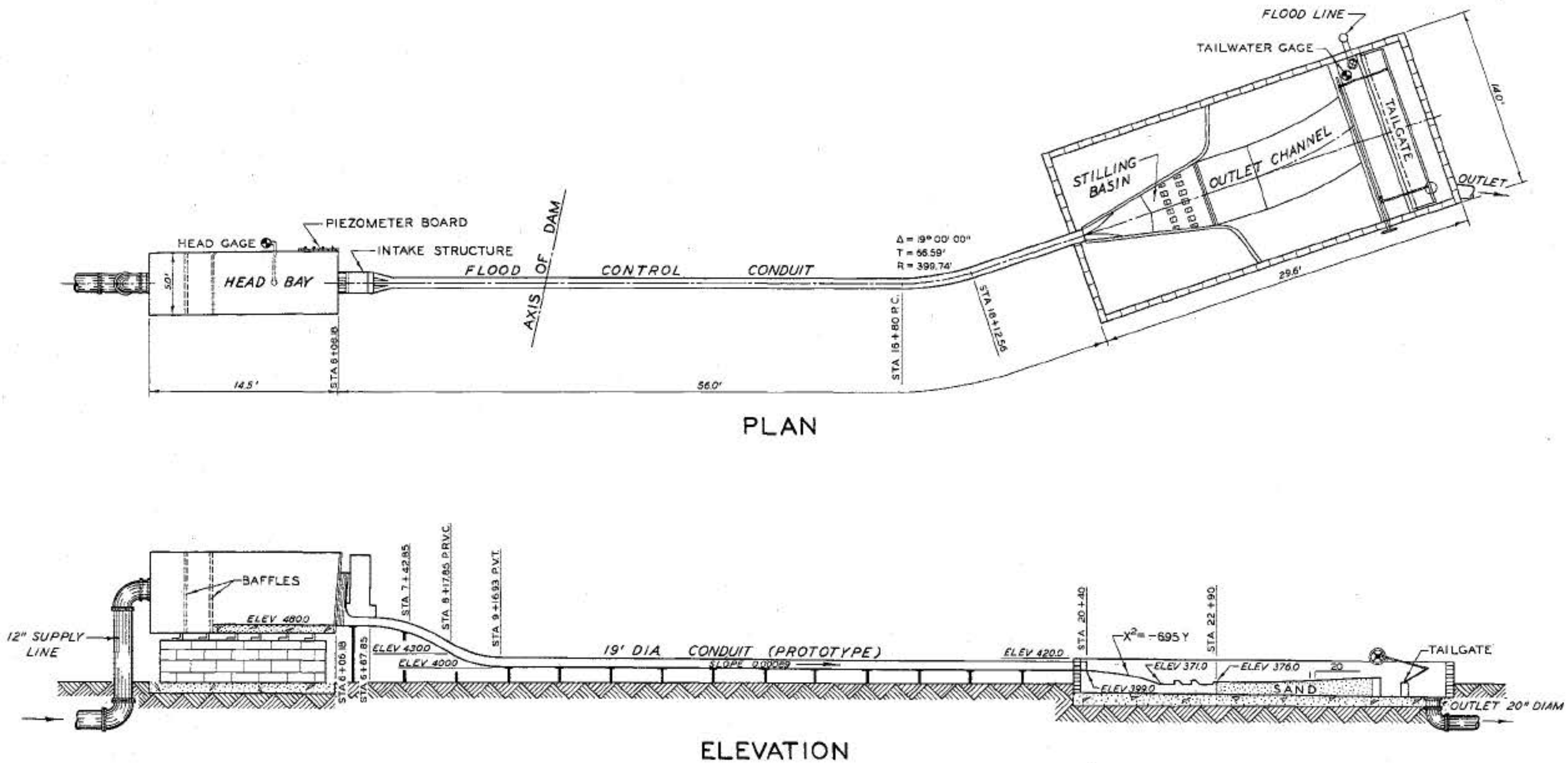
OUTLET WORKS PLAN

SCALE IN FEET

100 0 100 200 300 400

PLATE 1

PLATE 2

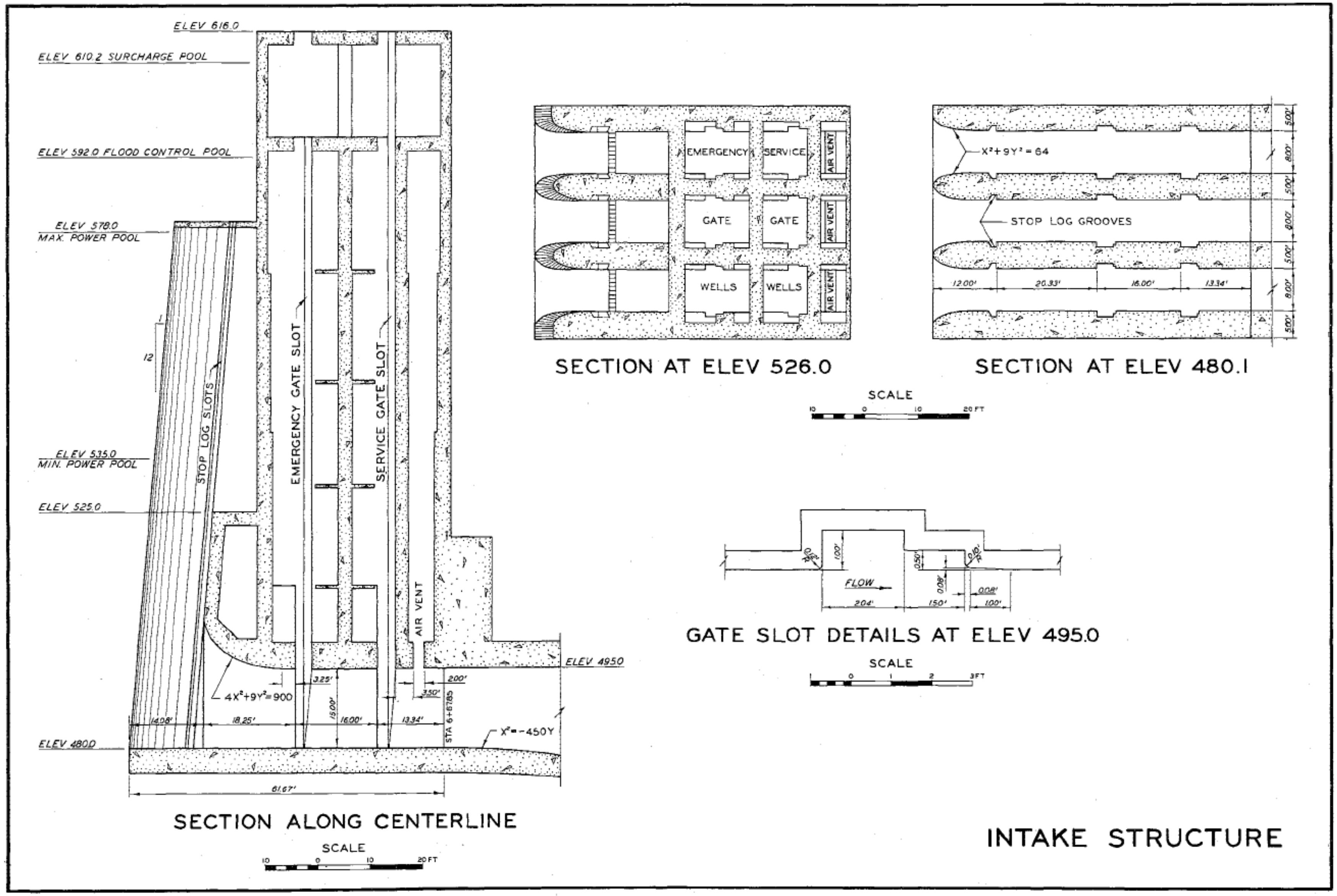


MODEL LAYOUT

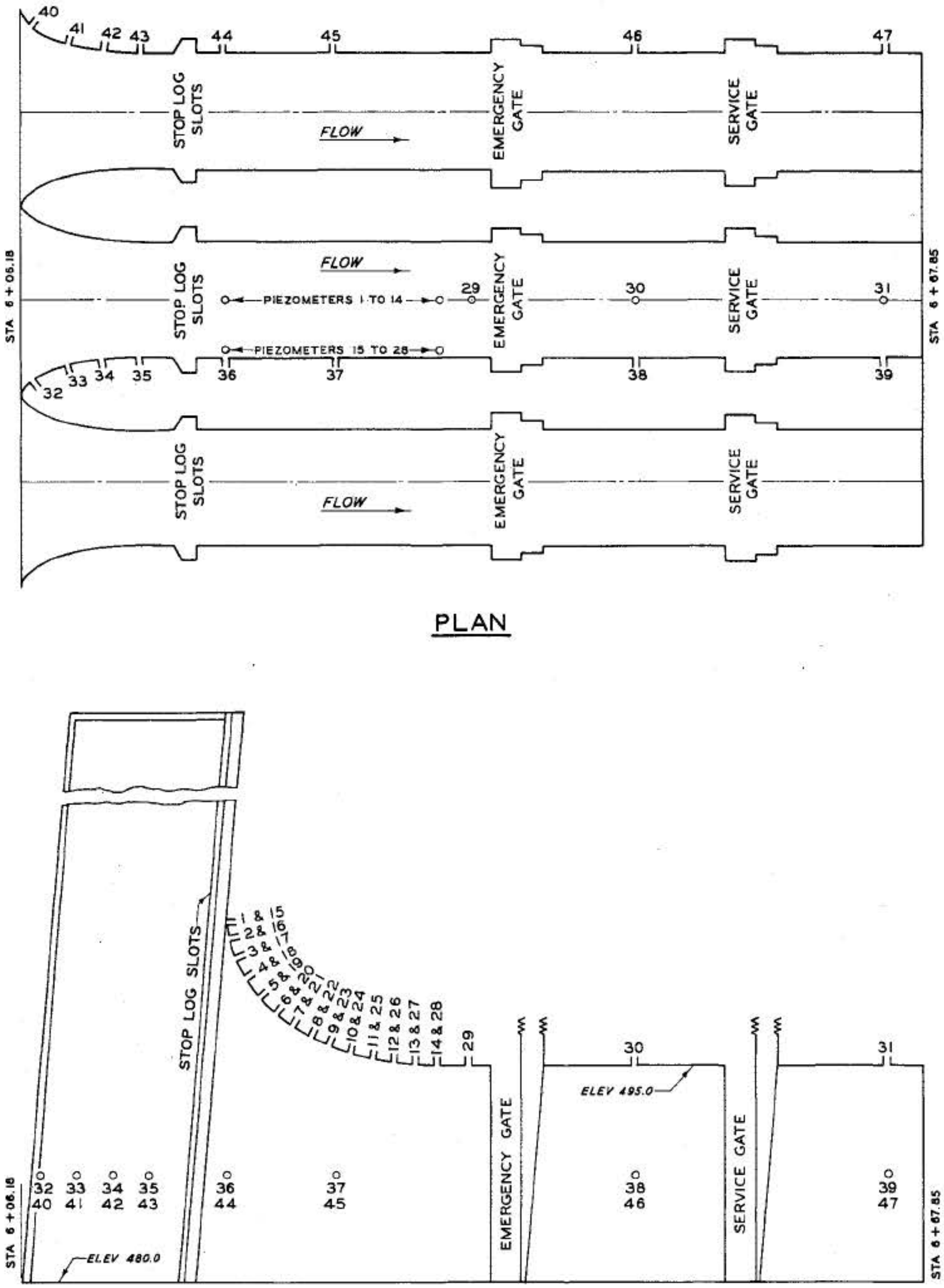
SCALES

PROTOTYPE 100 0 100 200 300 400 FT

MODEL 4 0 4 8 12 16 FT



INTAKE STRUCTURE



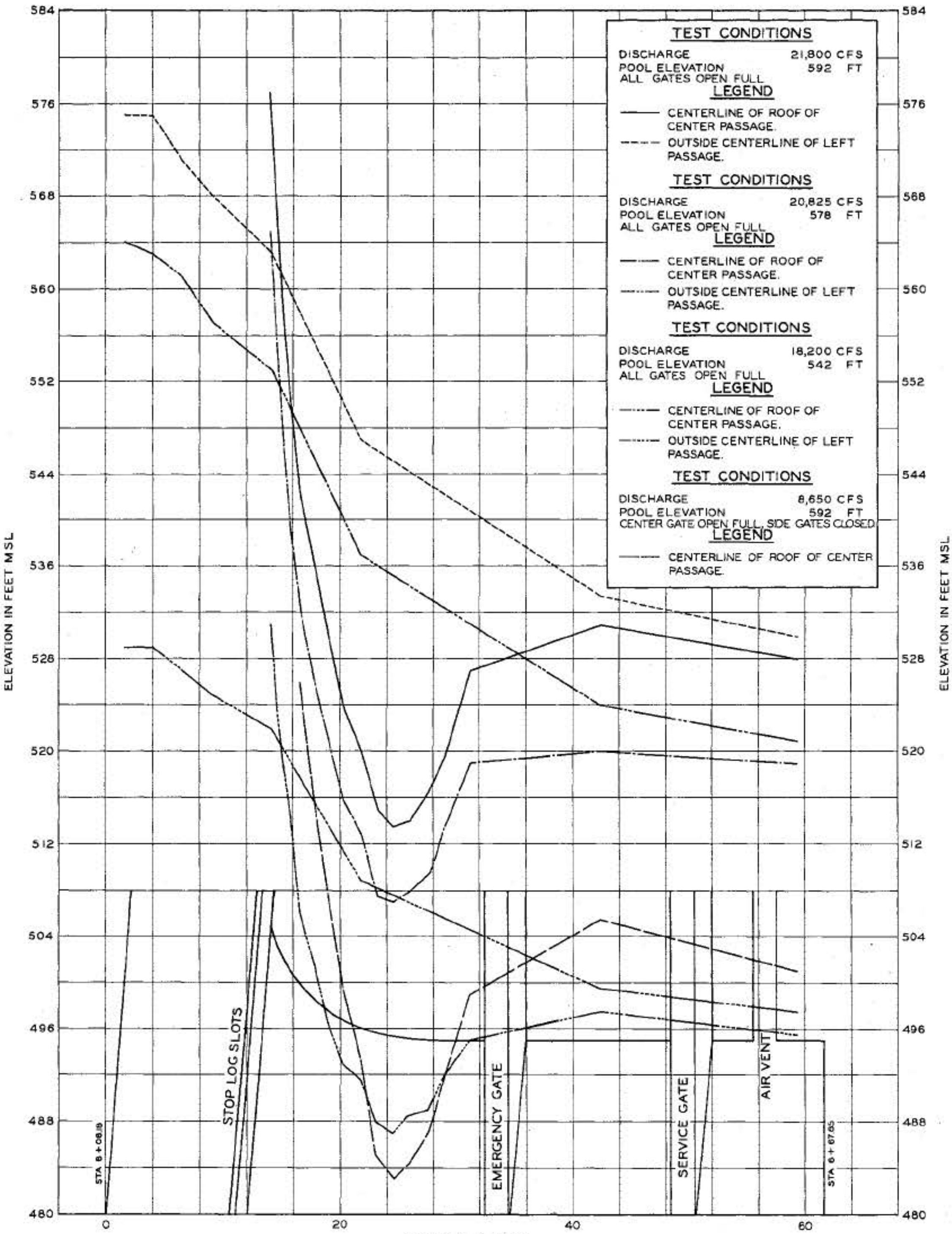
MODEL STUDY OF OUTLET WORKS
BLAKELY MOUNTAIN DAM
OUACHITA RIVER, ARKANSAS

PIEZOMETER LOCATIONS INTAKE STRUCTURE

SCALE IN FEET

4 0 4 8 12

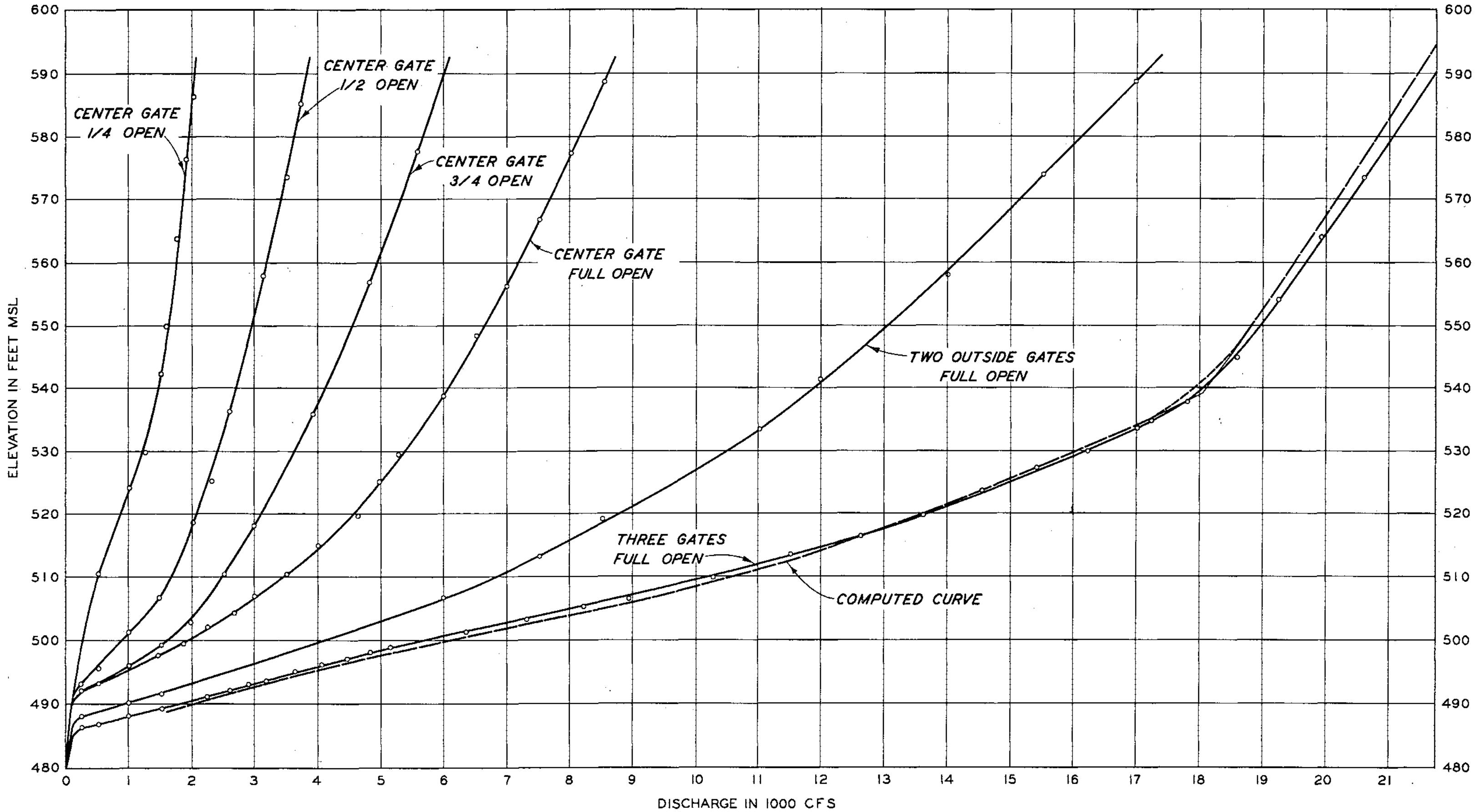
NOTE: SEE TABLE I FOR STATIONING OF PIEZOMETERS.



NOTE: GATE PASSAGES OPEN AS SHOWN IN LEGEND.

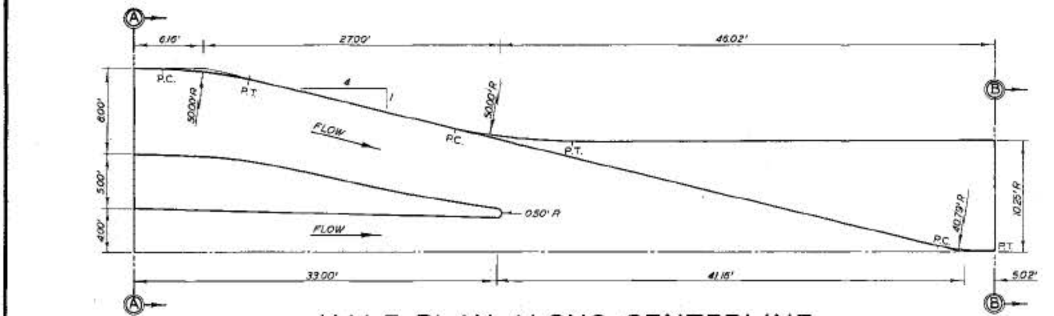
PRESSURE GRADIENTS THROUGH INTAKE STRUCTURE

PLATE 6

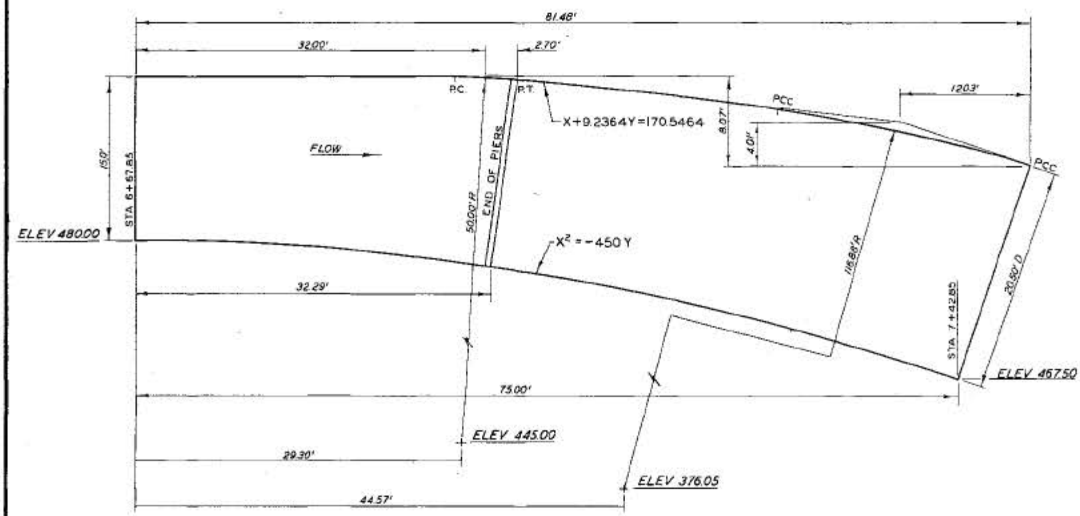


DISCHARGE CURVES

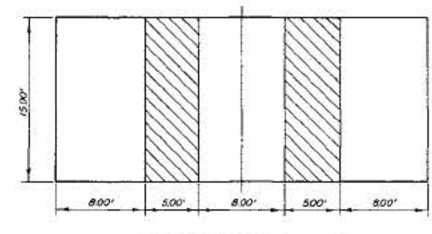
FULL AND PARTIAL GATE OPENINGS



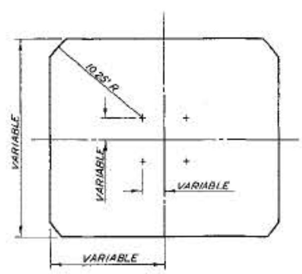
HALF PLAN ALONG CENTERLINE



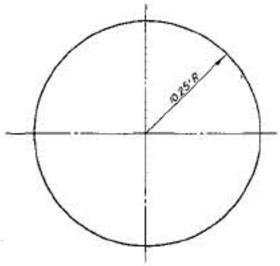
ELEVATION ALONG CENTERLINE



SECTION A – A



TYPICAL SECTION
DOWNSTREAM FROM PIERS

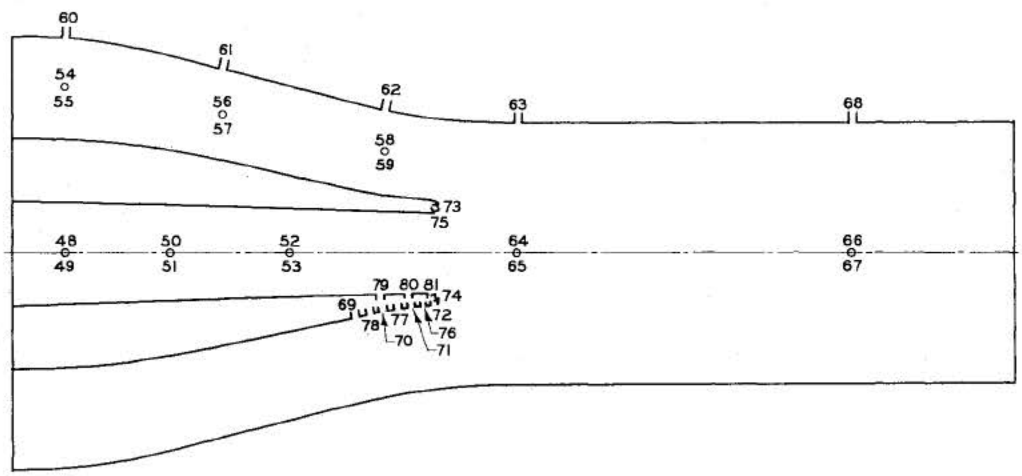


SECTION B – B

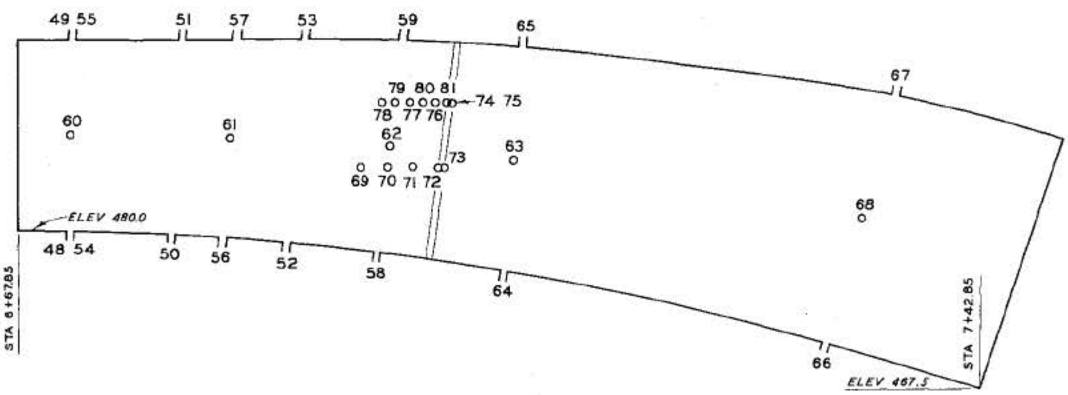
NOTE: APPROXIMATELY 8 PERCENT AREA REDUCTION BETWEEN SECTION A-A AND BEGINNING OF RECTANGULAR TO CIRCULAR TRANSITION.

ORIGINAL TRANSITION
SECTIONS 1 AND 2

SCALE
5 0 5 10 15 20 FT



PLAN



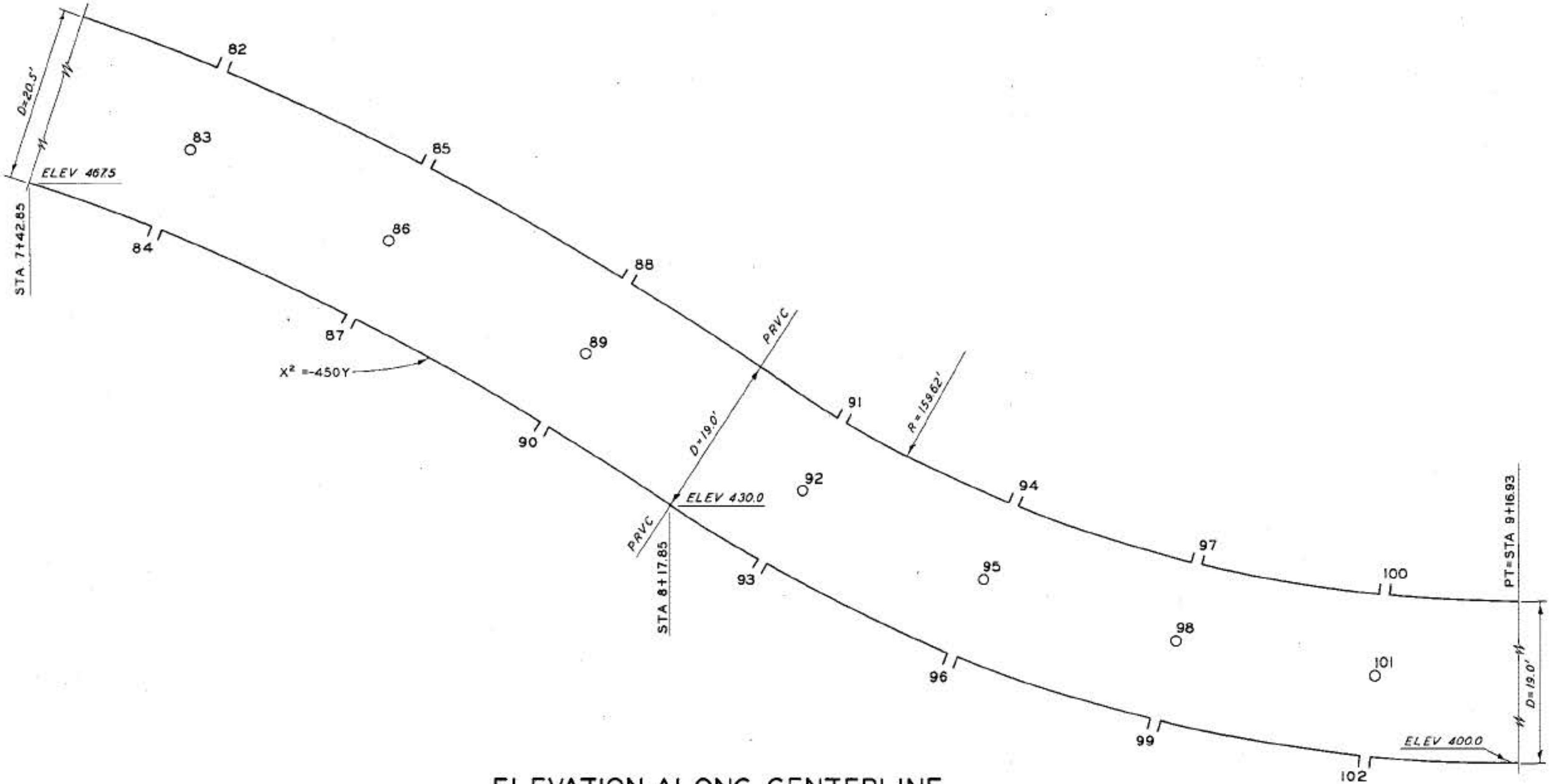
ELEVATION

NOTE: SEE TABLE I FOR STATIONING OF PIEZOMETERS.

PIEZOMETER LOCATIONS IN CONDUIT TRANSITION

SCALE IN FEET

5 0 5 10 15 20



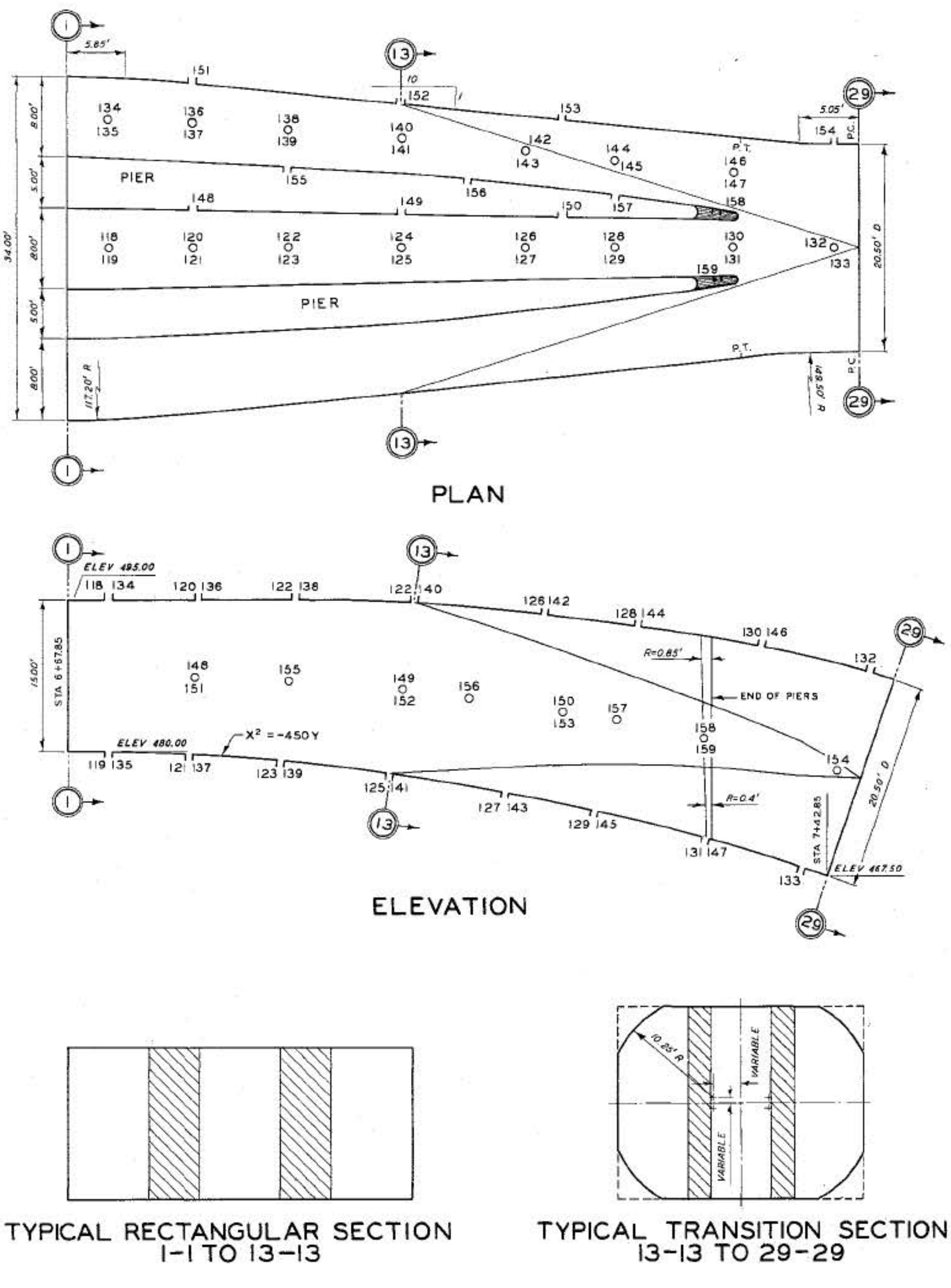
ELEVATION ALONG CENTERLINE

NOTE: SEE TABLE I FOR STATIONING OF
PIEZOMETERS.

PIEZOMETER LOCATIONS IN DROP - DOWN

SCALE IN FEET

6 0 6 12 18 24



NOTE: THE VERTICAL ALIGNMENT REMAINED IDENTICAL TO THE ORIGINAL DESIGN SEE PLATE 7

SECTIONS PROVIDE A CONSTANT REDUCTION IN AREA.

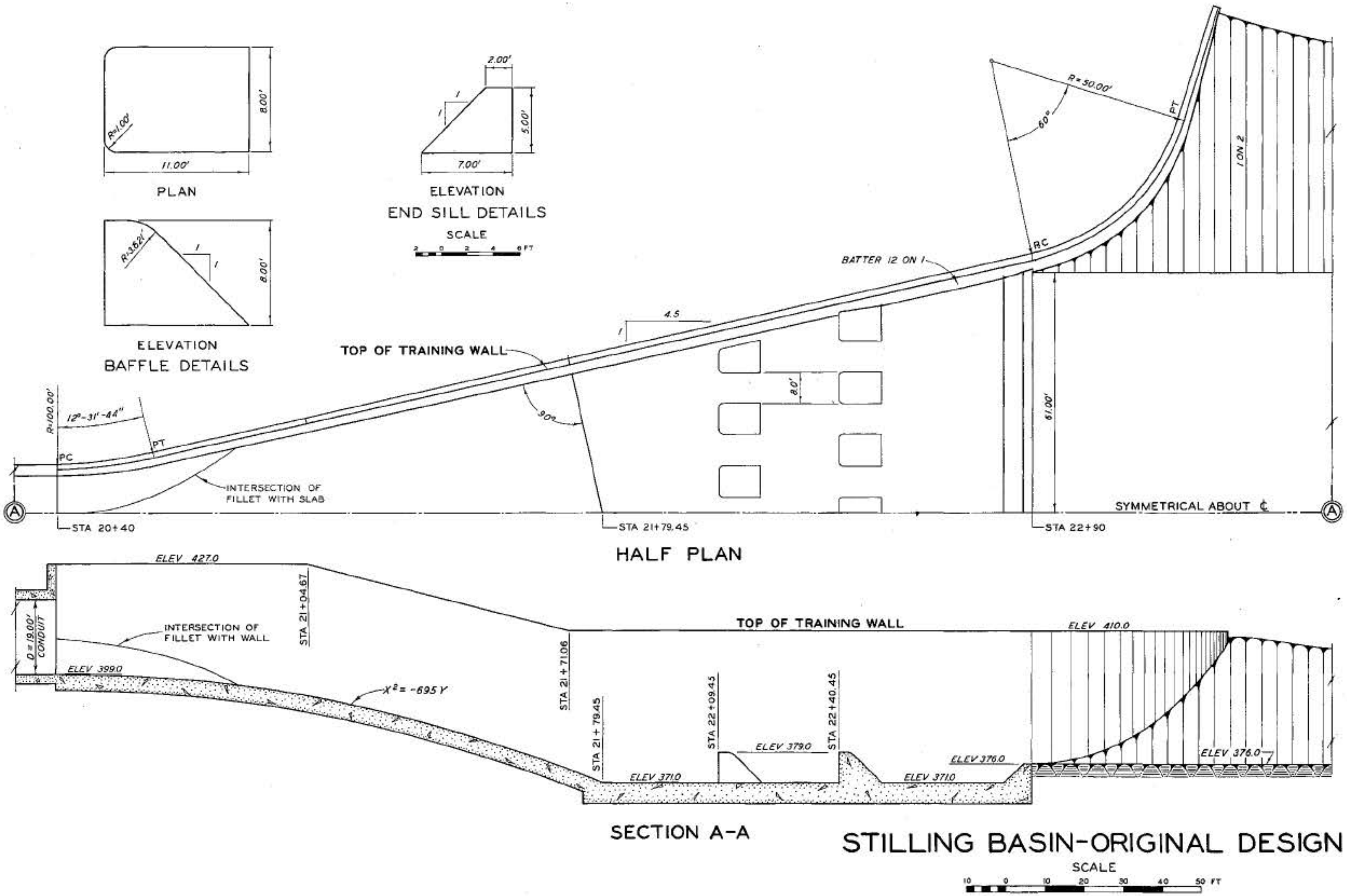
TRANSITION SECTIONS CONFORM TO CONVERGING FILLETS WITH A CONSTANT RADIUS.

TABLE 3 SHOWS STATIONING OF PIEZOMETERS.

REVISED TRANSITION WITH PIEZOMETER LOCATIONS

SCALE

5 0 5 10 15 20 FT

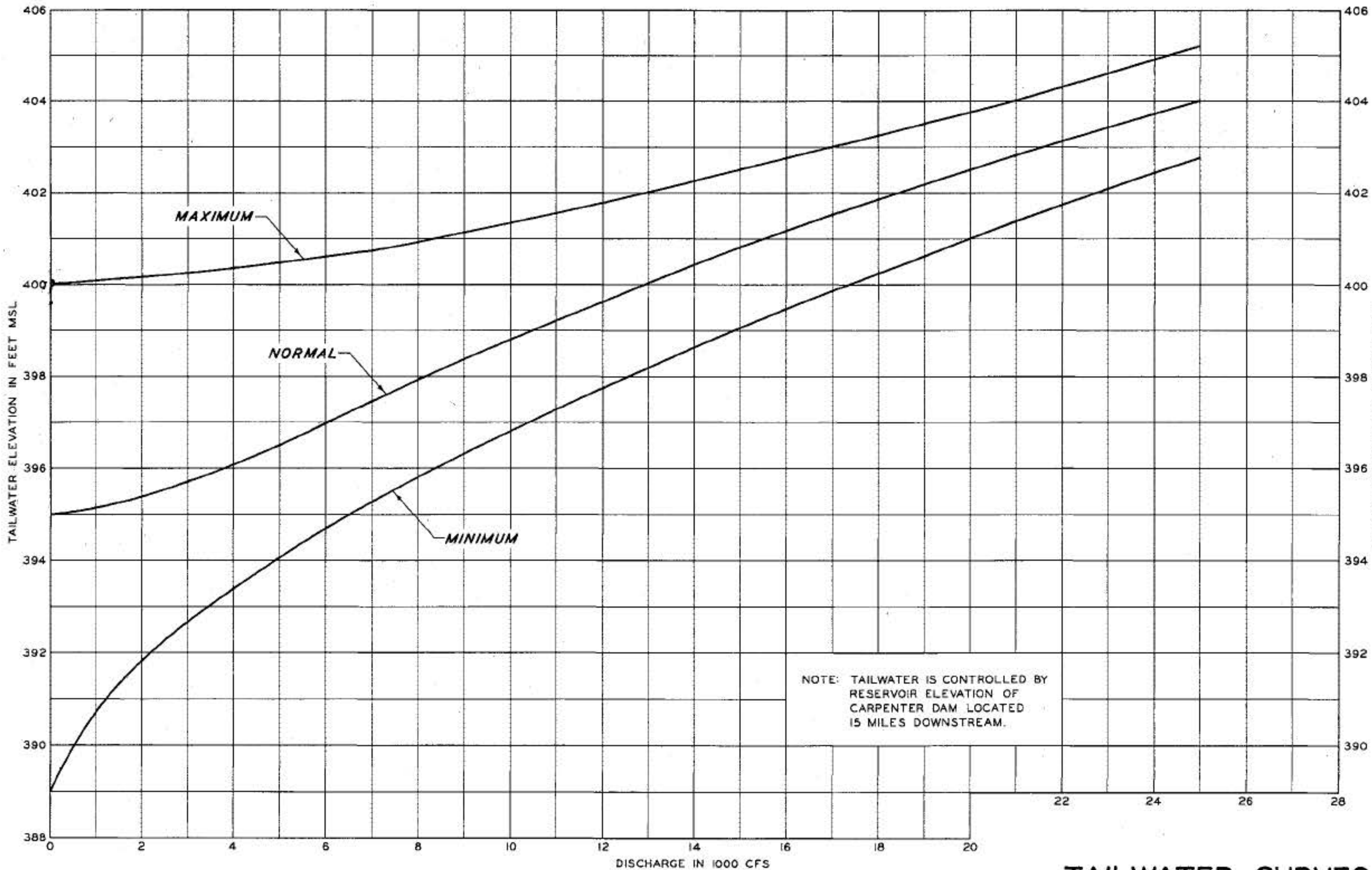


STILLING BASIN-ORIGINAL DESIGN

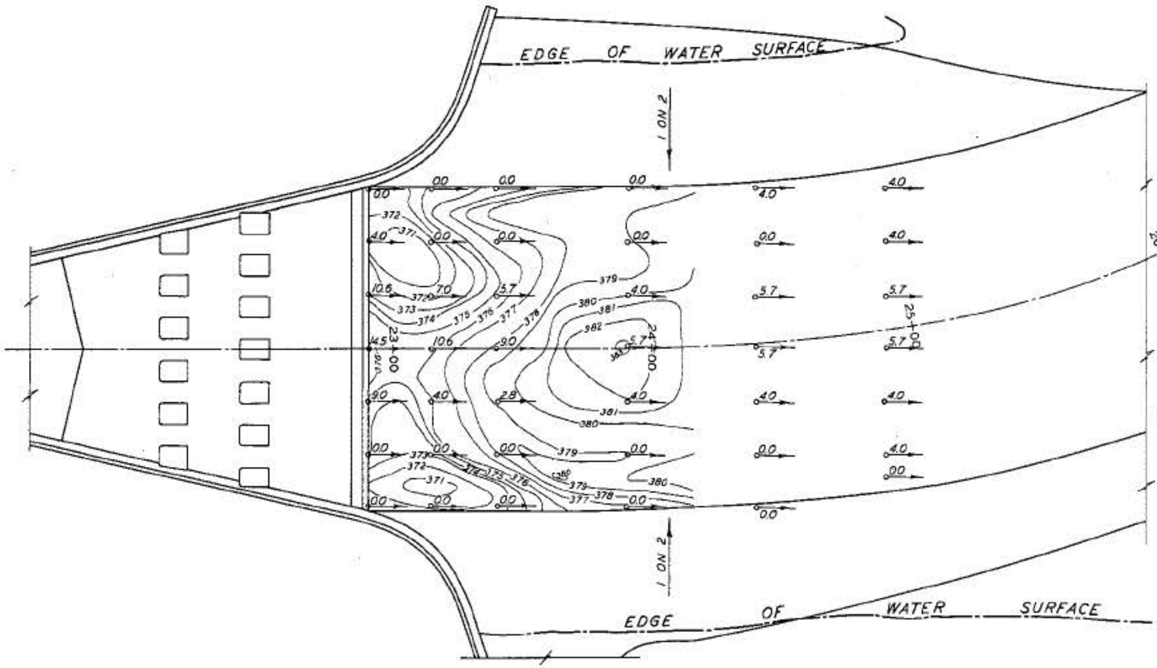
SCALE

PLATE 11

PLATE 12



TAILWATER CURVES



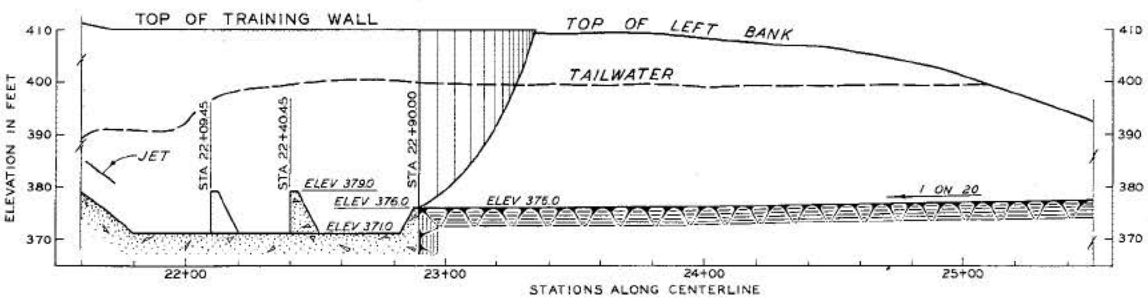
SCOUR PATTERN AND VELOCITY DISTRIBUTION

SCALE IN FEET

TEST CONDITIONS

CENTER GATE OPEN; SIDE GATES ½ OPEN	
DISCHARGE	15,000 CFS
POOL ELEVATION	580.0 FT
TAILWATER ELEVATION	399.0 FT

NOTE:
1. EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
2. MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
3. EXIT CHANNEL BED MOLDED IN MORTAR FOR VELOCITY MEASUREMENTS.
4. VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM.
5. ZERO VELOCITY INDICATES SLIGHT MOVEMENT IN DIRECTION SHOWN.

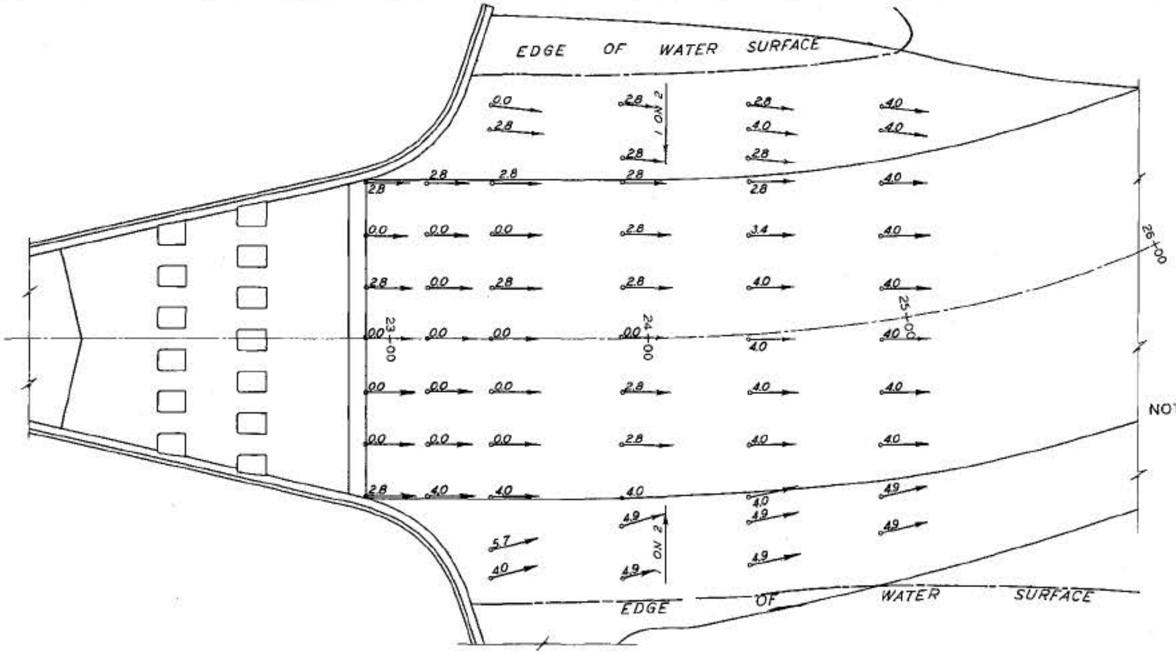


WATER-SURFACE PROFILE

MODEL STUDY OF OUTLET WORKS
BLAKELY MOUNTAIN DAM
OUACHITA RIVER, ARKANSAS

STILLING BASIN ACTION

TYPE I-ORIGINAL BASIN DESIGN



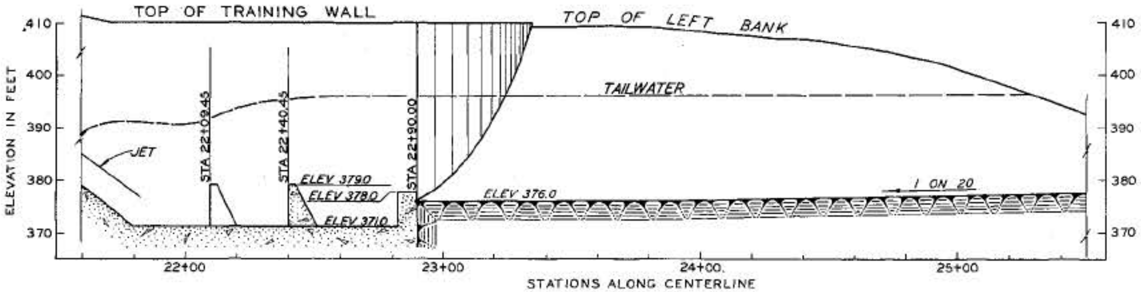
VELOCITY DISTRIBUTION

SCALE IN FEET

TEST CONDITIONS

CENTER GATE OPEN; SIDE GATES CLOSED	
DISCHARGE	8,650 CFS
POOL ELEVATION	592.0 FT
TAILWATER ELEVATION	396.0 FT

NOTE: 1. EXIT CHANNEL BED MOLD IN MORTAR FOR VELOCITY MEASUREMENTS.
2. VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM.
3. ZERO VELOCITY INDICATES SLIGHT MOVEMENT IN DIRECTION SHOWN.

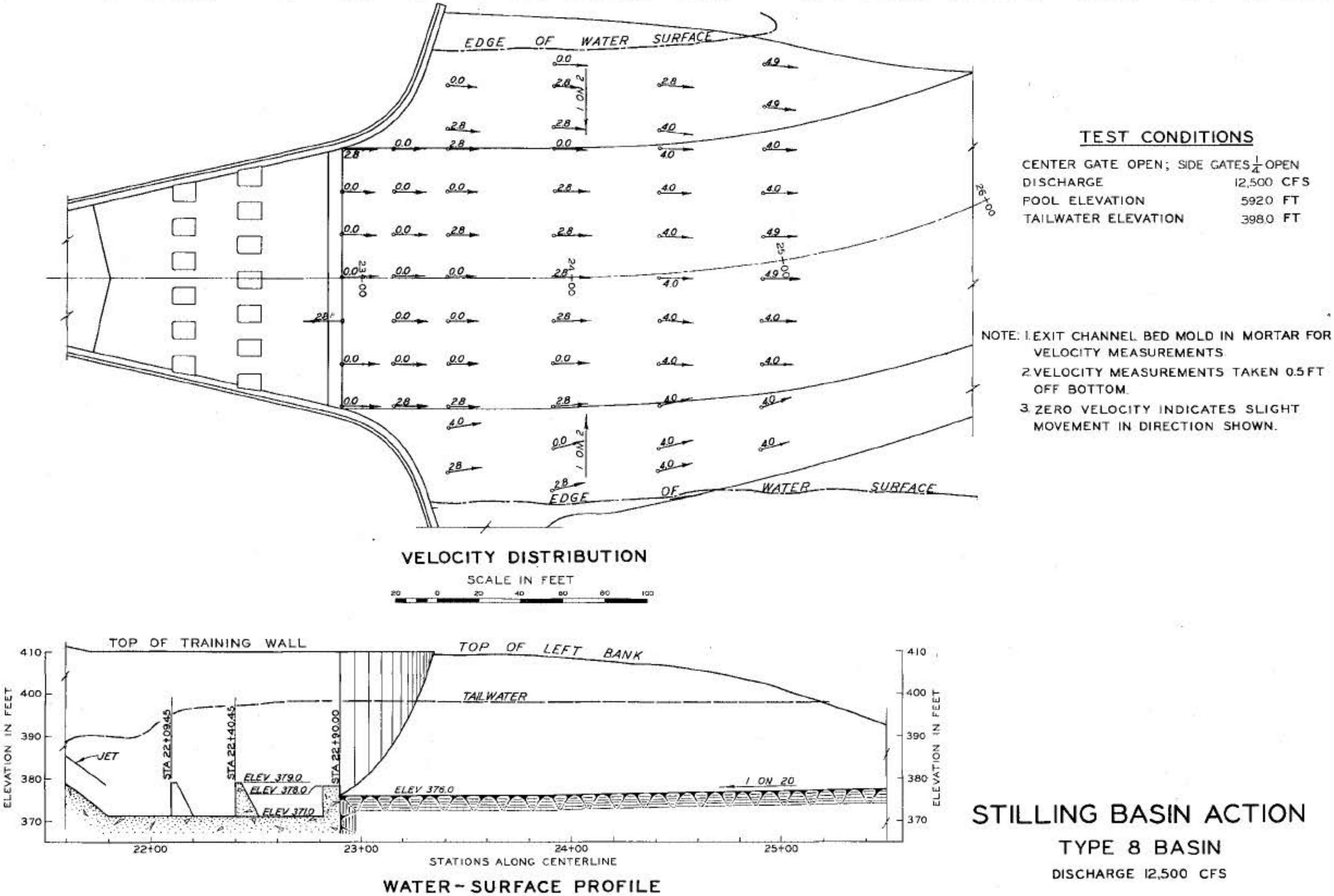


WATER-SURFACE PROFILE

STILLING BASIN ACTION

TYPE 8 BASIN

DISCHARGE 8,650 CFS

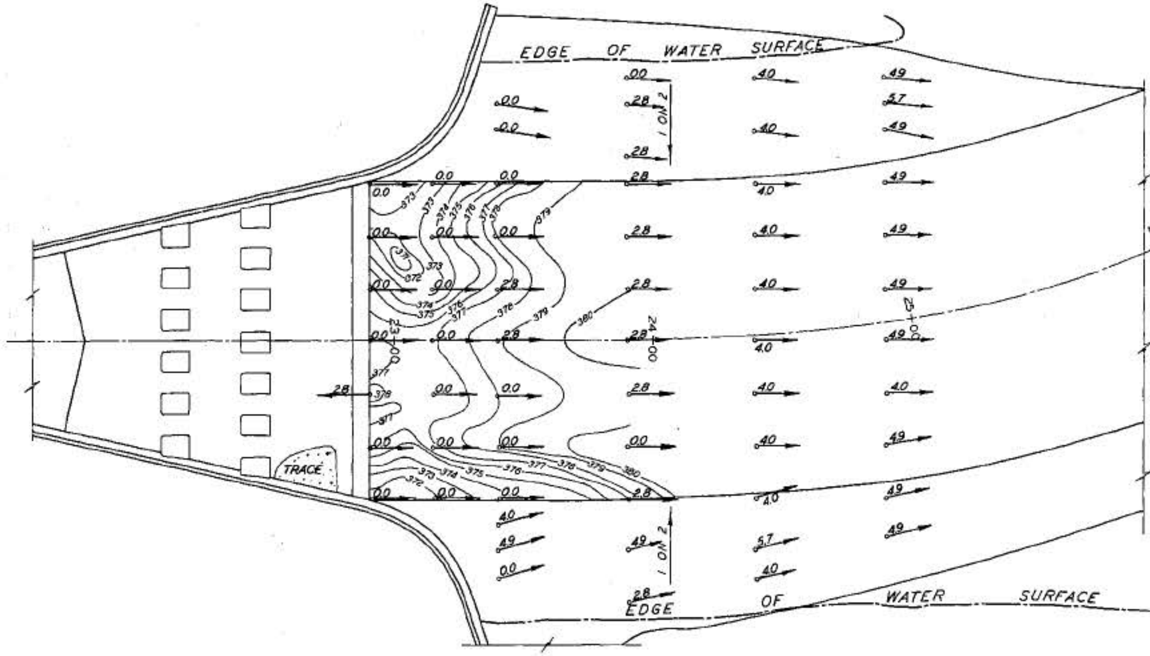


STILLING BASIN ACTION

TYPE 8 BASIN

DISCHARGE 12,500 CFS

PLATE 16



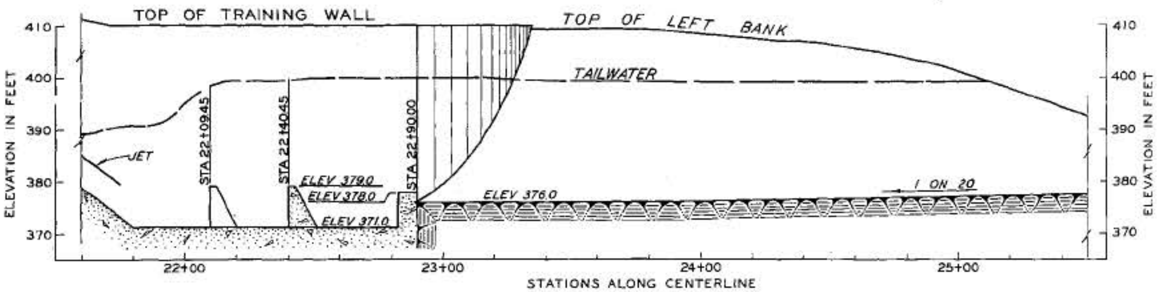
TEST CONDITIONS

CENTER GATE OPEN; SIDE GATES $\frac{1}{2}$ OPEN	
DISCHARGE	15,000 CFS
POOL ELEVATION	580.0 FT
TAILWATER ELEVATION	399.0 FT

NOTE:
1. EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
2. MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
3. EXIT CHANNEL BED MOLD IN MORTAR FOR VELOCITY MEASUREMENTS.
4. VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM.
5. ZERO VELOCITY INDICATES SLIGHT MOVEMENT IN DIRECTION SHOWN.

SCOUR PATTERN AND VELOCITY DISTRIBUTION

SCALE IN FEET

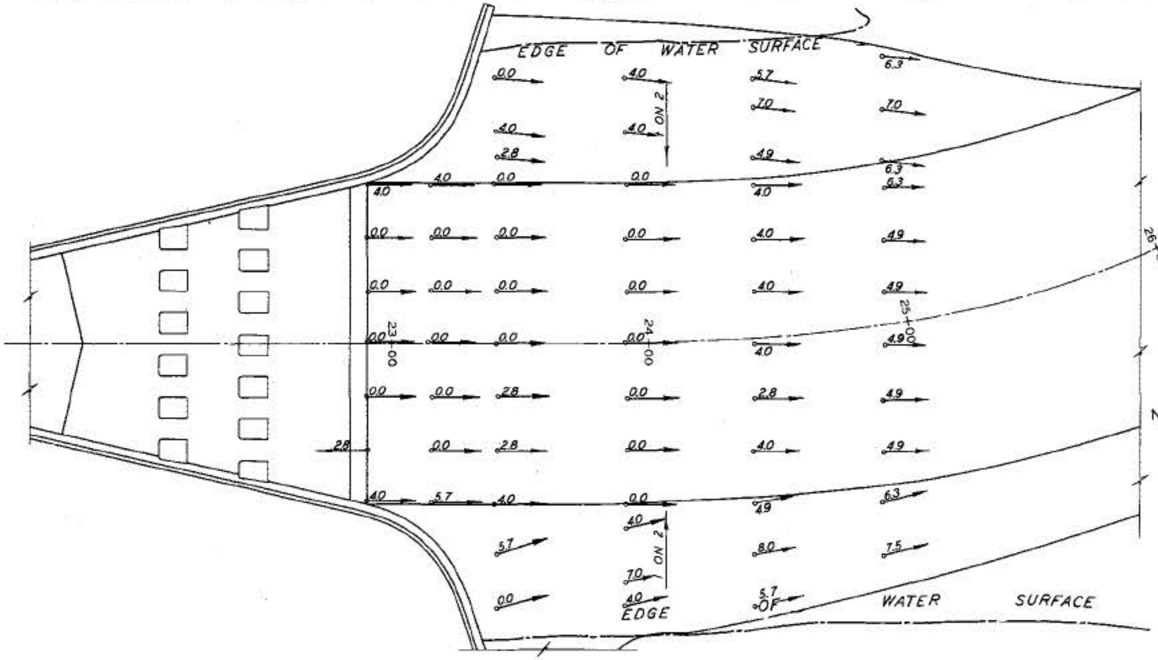


WATER-SURFACE PROFILE

STILLING BASIN ACTION

TYPE 8 BASIN

DISCHARGE 15,000 CFS



VELOCITY DISTRIBUTION

SCALE IN FEET

20 0 20 40 60 80 100

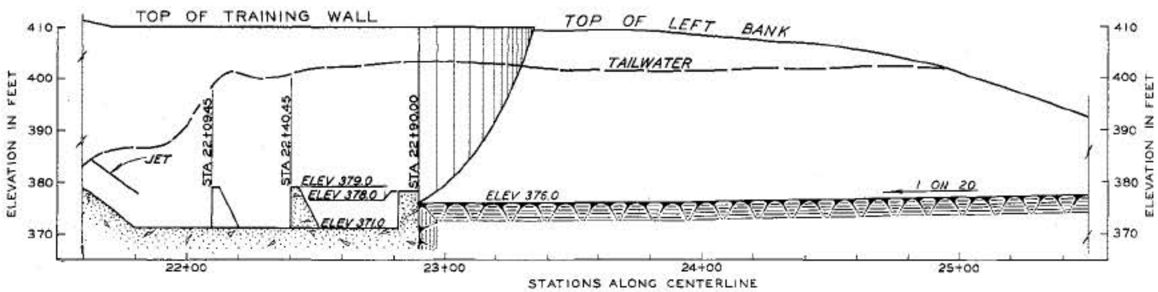
TEST CONDITIONS

ALL GATES OPEN	
DISCHARGE	21,800 CFS
POOL ELEVATION	592.0 FT
TAILWATER ELEVATION	401.6 FT

NOTE: 1. EXIT CHANNEL BED MOLD IN MORTAR FOR VELOCITY MEASUREMENTS.

2. VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM.

3. ZERO VELOCITY INDICATES SLIGHT MOVEMENT IN DIRECTION SHOWN.

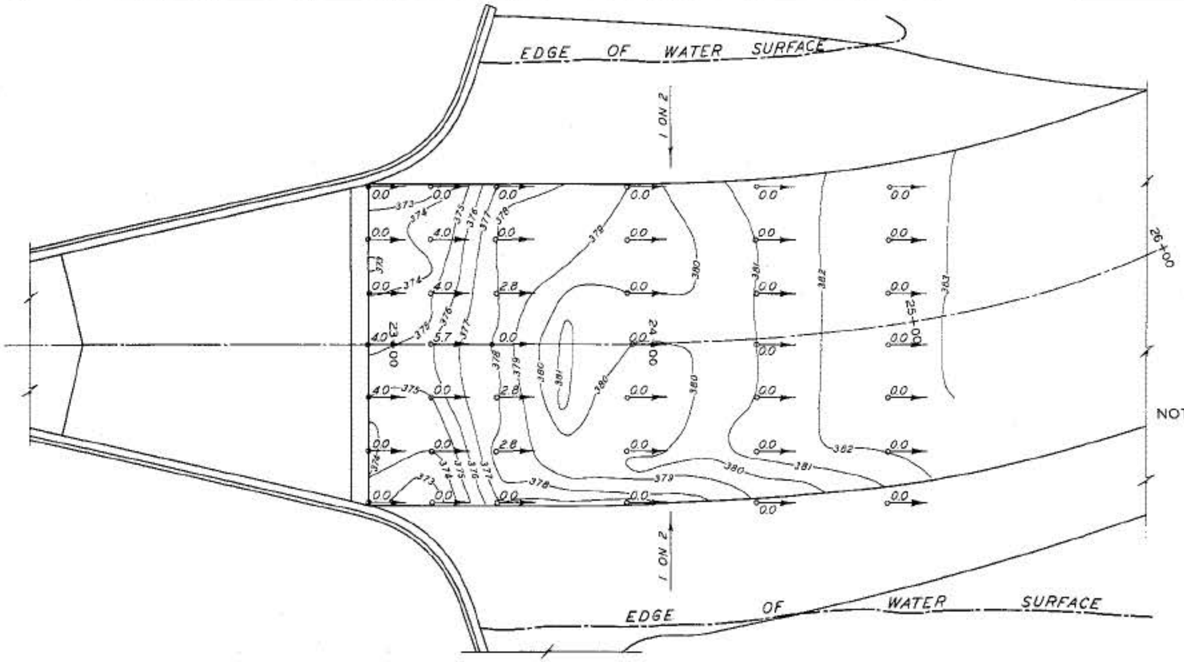


WATER-SURFACE PROFILE

STILLING BASIN ACTION

TYPE 8 BASIN

DISCHARGE 21,800 CFS



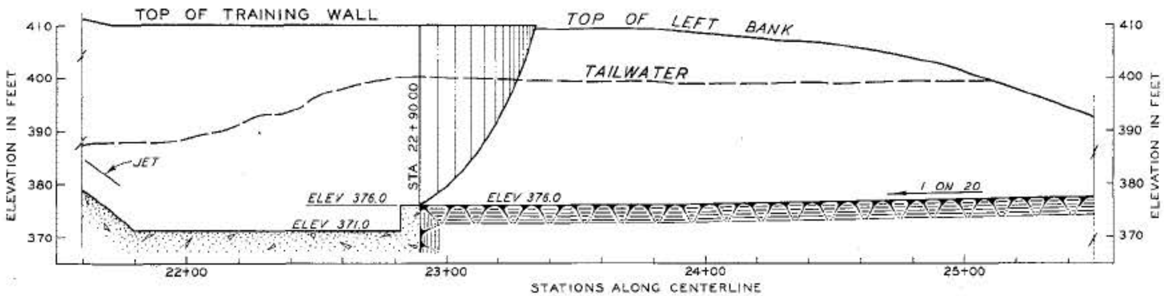
SCOUR PATTERN AND VELOCITY DISTRIBUTION

SCALE IN FEET

TEST CONDITIONS

CENTER GATE OPEN; SIDE GATES $\frac{1}{2}$ OPEN	
DISCHARGE	15,000 CFS
POOL ELEVATION	580.0 FT
TAILWATER ELEVATION	399.0 FT

NOTE:
1. EXIT CHANNEL BED MOLDED IN SAND FOR SCOUR PATTERN.
2. MODEL OPERATED ONE HOUR TO OBTAIN SCOUR PATTERN.
3. EXIT CHANNEL BED MOLD IN MORTAR FOR VELOCITY MEASUREMENTS.
4. VELOCITY MEASUREMENTS TAKEN 0.5 FT OFF BOTTOM.
5. ZERO VELOCITY INDICATES SLIGHT MOVEMENT IN DIRECTION SHOWN.
6. NO BAFFLE PIERS.



WATER-SURFACE PROFILE

STILLING BASIN ACTION

TYPE 5 BASIN